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TECHNICAL EVALUATION AND TESTING OF RUGGEDIZATION OF THE CT SCANNER

SUBTITLE: DEVELOPMENT OF A SIGHTING DEVICE FOR THE HAND-HELD DENTAL X-RAY

FINAL REPORT

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SEPTEMBER 30, 1992

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U.S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND
Fort Detrick, Frederick, Maryland 21702-5012

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U.S. Army Laboratory Command
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Phase II of the X-Ray Sight project was the result of the work of many individuals. Most of the mechanical layout and design was performed by Eugene Marquis, fabrication of the circuit boards was done by Ron Frankel of TA-SS, metal parts were fabricated by the Mechanical Technology Branch (ES-MT), and the bore sights and last-minute modifications by Russell Thayer.

Introduction

This report covers the development of a prototype x-ray sighting device for the U.S. Army Medical Materiel Development Activity (USAMMDA) under MIPR 91MM1560. This effort was conducted by the Mechanical Systems Branch of Harry Diamond Laboratories (HDL) over the period FY 91-92.

The goal of this effort was to develop a device to allow the use of the Hand-Held Dental X-Ray (HDX) in more general medical applications. Such applications require the x-ray source to be placed at a known distance from the film plane, with indications of where the beam will fall.

This effort consisted of two parts. The first phase encompassed the development of the design approaches, and resulted in a prototype device (dubbed XRS, or x-ray sight). This development is covered in an interim report dated 19 Mar 92, included as Appendix A. The initial phase settled on a sighting device utilizing four solid state lasers mounted on the corners of a metal horn, which would define the x-ray beam. The lasers would indicate the locations of the corners of the x-ray beam at the film plane at various source-to-image distances (SID). The precision location of the beam extents is important because federal safety regulations mandate that the operator know where the beam is to within a given tolerance.

The second phase involved refinement of the XRS prototype, and the fabrication of five units. The XRS prototype was presented to USAMMDA in 2Q FY92, and changes were proposed shortly thereafter. HDL refined the design and another review was held in May of 92. The concept for the refined prototype, designated XRS2, was presented to USAMMDA, and a few final changes were requested. Design and fabrication of five units plus one set of bore sighting equipment proceeded through 3Q FY92, with delivery at the close of FY92.

This report centers on the changes made to the original XRS which resulted in XRS2, as well as suggested further refinements.

Mechanical Design

Several changes in the mechanical design were made during this period. These were based on requests from USAMMDA, FDA requirements, and the HDL designers. These are summarized in this section. The mechanical drawings are included in Appendix B.

Safety Rod

FDA requirements call for a means of preventing the operator from getting closer than 12" SID on x-ray equipment. The original XRS did not meet this requirement, so a safety rod was added to XRS2.

The safety rod is made of lexan, as it is relatively transparent to x-rays. In the operating position, the rod extends into the path of the beam. The rod is hinged atop the XRS2 and incorporates a safety plate which covers the HDX beam controls when the rod is in the stowed position. Clips secure the rod in both the stowed and deployed positions. In order to use the HDX with the XRS2 attached, the operator must flip the rod up out of the way. As the rod is loosely hinged, the operator must then clip it into its deployed position to immobilize it.

It is felt that the current design is sufficient to preclude an operator from violating the 12" rule. The safety rod does not, however, preclude malicious operation of the HDX with the operator or patient within 12". Though inconvenient, the operator can deploy the device only partially, unclipping it from the stowed position leaving enough clearance to access the HDX controls. The operator can also operate the HDX without the XRS2 attached and potentially have direct access to the x-ray source. These scenarios fall outside the area of normal use by a trained operator and are not expected to pose a credible hazard.

Power Supply

The original XRS was powered by a 9V battery for demonstration purposes. HDL had planned to power the XRS by adding a power jack to the HDX. This approach seemed logical as it eliminated the need for a separate supply for the XRS. Also, if the HDX batteries were depleted, the XRS wouldn't be needed either, so sharing a supply seemed an appropriate path.

Early HDL designs postulated a 'T' adapter between the HDX power supply and the HDX power cable. The was rejected by USAMMDA due to concerns of increased resistance to the power path. During the design of XRS2, HDL proposed adding a connector to the HDX which would draw power from terminals within the HDX. This would eliminate any additional resistance in the power path. An examination of a prototype HDX at HDL showed that such an adaptation was possible, the only modification being a hole in the HDX housing for the connector.

This approach was rejected by USAMMDA due to the logistical difficulty of modifying existing HDX's and the fact that the existing HDX's were all prototypes. The final design could differ from the prototypes, possibly precluding this type of modification. USAMMDA expressed a desire to have the XRS contain its own power source, to consist of readily available disposable batteries. Standard commercial batteries would ease the logistical burden, and would lessen the downtime caused by recharging embedded NiCd cells.

Due to space constraints within the XRS2, the power supply choice was limited to AA size batteries. Four were chosen to provide 6VDC nominal. This eliminated the need for voltage regulation within the XRS2, as the electronics and lasers could both operate at 6VDC. Designs utilizing power from the HDX would have required a DC-DC converter module to step the HDX 24VDC down to 5VDC. These modules were approximately the size and weight of the newly included battery pack, and cost approximately $100.

The battery system for the XRS2 comprises a removable panel on one side of the XRS2 which covers the batteries, a battery holder, and an interior bracket. The batteries are mounted in a standard four-cell flat package secured to the bracket which is attached to the inner wall of the XRS2 housing. The panel is sealed with a Poron gasket and secured to the housing with eight screws. This design does not require disassembly of the XRS2 simply to replace the batteries.

Operator Control

The original XRS operator interface consisted of an on/off switch and an illumination button with an integral LED indicator. The on/off switch was included for demonstration purposes when the XRS was running on its internal battery. The controls were mounted on a raised sloped panel which extended over the top of the HDX to place the XRS controls just above the HDX beam controls. While functional, the addition of this extra panel involved several parts and had the potential for fit/finish problems.

The original electronics in the XRS were designed to be used in conjunction with an on/off switch, which eventually would have been replaced by taking power from the HDX. With this scheme abandoned, this approach to the electronics design was no longer appropriate. The changes in the XRS2 electronics are discussed in later sections. The new design required only a single push-button, which would power the lasers for approximately 10 seconds.

The button used in the original XRS was difficult to mount. In order to fit in the limited space behind the sloped panel, the button chosen was essentially a flush-mount design. This type of button is intended for mounting directly on a printed circuit board, as opposed to mounting through a panel. This configuration is not desirable for several reasons.

By not mounting through a hole in the panel, the button would be difficult to seal. The hole in the panel for this type of button is merely a clearance hole, allowing the button to protrude. The button is physically mounted on a circuit board suspended behind the panel.

This type of button mounting requires many parts. The button must be mounted on a circuit board which is held in place by several standoffs and screws. The resultant panel design, even when optimized for manufacture, could still require several parts to create an enclosed assembly.

These buttons are not designed to carry more than a few milliamps of current. Their purpose is small signal switching. A single control (no on/off switch) in XRS2 would have to carry the full current load (>100mA) for a short time, until the internal relay was activated. Even though the time period was short, it was felt the this type of switch would be unreliable at these power levels.

An HDL design goal for XRS2 was to devise a way to use a standard panel-mount push button. This type of button physically mounts in a hole in the panel, providing a seal. The drawback is that this type of button protrudes at least an inch behind the panel. The XRS sloped panel did not have enough room to mount a standard panel-mount switch.

The sloped panel was also slated for change. Experience with the original XRS proved that the panel system, while good from an ergonomic standpoint, was difficult to manufacture (in prototype quantities), and posed a potential sealing problem. Clearly a panel-mount button could simply be mounted through the top of the XRS housing, but it would be very awkward for the operator to use while holding the HDX. Ergonomic considerations dictated that the button be usable without the operator's hands leaving the HDX handles.

The design of the operator interface for XRS2 evolved into mounting the button in a small box attached to the side of the XRS2 housing. The separate button box could then be mounted at the optimum angle and extension to place the button within easy reach of the operator.

Going to a single button control negated the added safety of having two control actions required to illuminate the lasers. In the original design, a separate on/off switch insured that the operator had to perform two actions (turn the switch on and press the button) in order to emit laser radiation. The design of the XRS2 incorporates a cover over the button which must be flipped up before the button can be pressed. This should lessen the possibility of inadvertent laser emissions.

Weather Sealing

During the design review for XRS2, USAMMDA requested that future versions be sealed against the weather. Though no formal specifications were imposed, it was agreed that the XRS2 should be sealed against dirt, water splash, and light rain. Several features were added in support of this request.

Poron gaskets were added to the metal/metal interfaces. The housing was redesigned with a flange to butt against the baseplate, and a gasket was added at that interface. As previously mentioned, the battery door also has a gasket seal.

A lexan panel was added to the inside of the housing to cover the openings for the horn and lasers. Lexan was chosen for its transparency to both x-rays and visible light. A lexan plug was also designed for the opposite end of the horn, where it joins the HDX.

Through-holes for screws in the baseplate were eliminated. All internal hardware now mounts in blind holes. The through holes for the four long attachment screws, which mount the XRS2 to the HDX, are shielded with metal tubes. These tubes are mounted to the baseplate and extend the depth of the housing. Poron gaskets on the housing interior seal the exposed ends of these tubes. The attachment screws pass through these tubes, protecting the interior of the XRS2 from the elements.

The attachment screws were also modified to remain captive within the XRS2 when not mounted on the HDX. E-rings snapped into grooves on the screws insure that the screws cannot be completely removed from the baseplate. HDL considered this a shortcoming in the original XRS, in which the long attachment screws had to be inserted through the baseplate blindly. This modification drastically reduces the mate/demate time of the XRS2.

X-Ray Horn

Another HDL goal for XRS2 was a redesign of the x-ray horn. The horn defines the footprint of the x-ray beam, so precision is important in order to meet the tolerances imposed on beam extent in the image plane.

The original horn was fabricated out of five pieces. Each of the four sides was a discrete part and these all mounted in a collar, which in turn mounted to the baseplate. This resulted in an assembly which could be prone to tolerance problems in a production environment. The assembly also allowed some radiation to escape along the seams, despite design features intended to minimize leakage.

The horn for XRS2 was designed as a single piece, including the baseplate mounting features. The inside of the horn was removed using electrical discharge machining (EDM). The EDM process utilizes a thin wire passing through the material and carrying a high voltage. The part to be machined is held at the opposite electrical potential, and the discharge occurring between the wire and the material forms a thin kerf through the part. This type of machining creates very precise parts and is well suited for cutting non-circular holes. The exterior of the horn was machined using traditional methods.

Boresight

The blank cut from the interior of the horn served as the base for a laser alignment fixture. The lasers in the XRS2 are mounted in adjustable carriers to allow for fine adjustment due to tight tolerances imposed on locating the corners of the x-ray beam. A simple fixture and alignment procedure was developed for XRS2, utilizing the waste from the EDM operation on the horn.

The blank is mounted on a vertical rod attached to a plate. The rod length is such that the lasers are aligned on an image at the intermediate SID. The validity of aligning the lasers at this distance was derived in the interim report. The plate has four targets on it to which the lasers are aligned. The XRS2 is perched upon the blank, pointed down. Access to the laser carriers required removal of the housing, which also removes the batteries and control button. A power connector is provided on the electronics board, enabling the lasers to be powered with a typical AC adapter (provided with the boresight). The use of the adapter saves the batteries during alignment, and also provides continuous power to the lasers (the 10 second timer is bypassed via the power connector).

Electronics Design

The electronics for XRS2 were completely redesigned. This was necessitated by requests from USAMMDA and the use of higher power lasers.

The original XRS prototype contained a small microcontroller which took care of the duty-cycle enforcement and controlled the power relay and buzzer. The elimination of the duty cycle (10 seconds on / 10 seconds off) and buzzer by USAMMDA essentially eliminated the need for the microcontroller. It should be noted that the microcontroller was used as a design expedient in the original XRS and probably would not have been carried over into production.

At this point, a simple ten-second timer was all that was needed. Pressing the control button would start a ten-second delay timer which would hold the power relay closed until the time expired. The move to battery power and higher powered lasers complicated the design.

Upon completion of the original XRS, it was determined that the lasers were too dim. They could not be seen at all in direct sunlight, and were difficult to see in bright room light. For the XRS2, more powerful lasers were ordered (1mW vs. .5mW). After receipt of these units, they too were found to be difficult to see in direct sunlight. It was decided that these units would be used in the XRS2 prototypes to demonstrate the principal. The user community will be able to provide further feedback on the adequacy of the lasers chosen. More powerful devices in the same package size are available (up to 8mW).

Higher power lasers naturally require more electrical power to operate. All of the lasers investigated during this task have been 5VDC devices, so the increased power requirements manifest themselves in higher operating current. The 1mW devices require a maximum current of 75mA.

The AA batteries chosen as the power source can only supply approximately 130mA, so all of the lasers could not be powered at once. This required a circuit to modulate the lasers in pairs, so only two were on at a time. The lasers are paired as opposite corners, so if one driver circuit malfunctions, a pair of diagonal corners would still be illuminated. The final circuit for the XRS2 consists of two IC's, three transistors, three capacitors, six resistors, and one relay. A detailed description of the circuit is presented in Appendix C.

Further Refinements

Several design refinements should be considered if development of the XRS2 continues. Due to time constraints on the redesign from the original XRS, these refinements could only be identified, but not pursued. The refinements are discussed below.

Mechanical Design

Laser Carriers

The design of the carriers for the lasers was simplified in XRS2, but these components could probably be simplified further. The adjustment method was also refined, the original XRS used compliant foam as the resistive member in the vertical adjustment of the lasers. Aging of the foam could result in misalignment due to material creep. The XRS2 uses a jackscrew arrangement, eliminating any compliant members in the adjustment.

Some simpler concepts for alignment were discussed, but were not pursued due to schedule constraints. The design of the carriers could also be simplified and they could be cast.

Safety Rod

The safety rod implemented on XRS2 is a simple design with safeguards to deter operation of the HDX without the rod deployed. Though effective, the exposed clips which secure the rod in the stowed and deployed positions could pose problems. Although the corners of the clips are rounded and the sharp edges broken, reliability problems could result from the clips being damaged in their exposed positions.

Two other basic designs were considered for the safety rod. The first design was similar to the prototype, utilizing a flip-up rod, but secured by ball and spring detents built into the hinge mechanism. The second design was a rod which slid through a collar mounted on the XRS2 housing, held in its stowed and deployed positions by ball and spring detents. This design had the potential drawback in that it might be easier to partially deploy than the flip-up arrangements.

Both of these approaches, and undoubtedly others, would eliminate the exposed clips present in the prototypes. User experience and feedback will best indicate if changes to the safety rod are required.

Though the material used in the safety rod was chosen by USAMMDA for its x-ray transparency, testing may be needed to confirm transparency of the rod. If the thickness of the rod causes an image on the film, a non-contact safety feature could be implemented. An ultrasonic range finder, similar to those used in Polaroid cameras, could be used to detect personnel within 12" SID. Though more expensive and complex, it is an alternative if the current design compromises image quality. This device could also be used to determine correct distances from the film plane when using the HDX in a fixed mounting position. This approach lacks the lock-out of the HDX controls that a more mechanical solution, such as the rod, provides.

Battery Access

The initial design for the battery door for XRS2 was a hinged door with captive quarter-turn fasteners. This design would have been slightly more complex and difficult to seal than the screw-fastened panel in the prototypes. The screw-fastened panel should be adequate for initial user evaluation, because the batteries should not have to be replaced too often.

Batteries could be a problem if higher powered lasers are required. The AA cells are near their current supply limit with the 1mW lasers in the XRS2. It may be difficult to package larger cells in a manner that doesn't require removal of the housing cover for replacement. This design concern will need to be addressed if USAMMDA requests the higher powered lasers.

Control Switch

A weather seal should be considered for the control switch. The manufacturer of this switch does offer a clear flexible boot which provides a splash resistant shield. This seal is not compatible with the use of the safety cover, which was deemed more desirable for the prototypes. Most switches investigated during the design offered both water resistance and a safety cover, but only in larger, industrial-type switches. If both features are desired, a further investigation will be conducted. Note that many of the boots offered start to lose pliability below 0°C.

The safety cover also needs field evaluation to determine its ruggedness. These covers were chosen to demonstrate the concept, but may not be rugged enough for field use.

Sealing

Some redesign should be done to conceal the gasket between the baseplate and the housing. The housing should have its mounting flange recessed, so that the baseplate and the gasket are concealed by the housing when assembled. This would result in a cleaner appearance and would protect the gasket from damage.

The electronics should be conformally coated with a sealant. The XRS2 prototypes were delivered uncoated, to permit modifications (such as laser frequency and "ON" time) after review by USAMMDA.

Electronics Design

Further refinements of the electronics design are centered around laser power and producibility improvements.

Lasers

It is understood that USAMMDA will evaluate the XRS2 in operational scenarios to determine if the lasers are bright enough under high ambient light conditions. If the HDX is to be used primarily in a clinical environment, current power levels may be sufficient. If there will be considerable outdoor use, power requirements may have to be reviewed.

Production versions of the XRS2 should utilize lasers with TTL control capability. This would allow the lasers to be controlled using low-level signals directly from the digital logic. Currently, the beams are modulated by turning the power to the laser on and off. This requires the use of discrete transistors to handle the power switching at the operating current of the lasers. Use of the TTL type of laser control would eliminate two transistors and two resistors from the circuit. Lasers are now available from the current supplier which have this capability.

The electronics could be further modified to operate only one laser at a time, as opposed to two. This would allow higher power lasers still utilizing AA batteries as the power source. This would complicate the electronics somewhat, but the ability to raise the optical power level without a larger power source would probably be a worthwhile tradeoff. If much higher power (several mW) were needed, the battery size would have to be increased.

Producibility

The issue of using a solid state power switch (such as a FET), as opposed to the relay, should be investigated. A FET may offer lower power consumption, as opposed to relay coil current. A solid state device may also offer higher reliability.

A production design should also examine the use of surface mounted components. These are not amenable to the prototyping board used for the deliverable units, but would offer a potential reduction in size and cost. If surface mount parts are used, more complex electronics, such as those to modulate all four lasers sequentially, could be accommodated in the same space as the current design.

Appendix A

Interim Report

This report describes the development of the initial XRS, and the various tradeoffs and system considerations which dictated the design approach.

Interim Report for MIPR 91MM1569
Design, Evaluation, and Fabrication
of X-Ray Sighting Device

19 March 1992

Submitted to
Commander, U.S. Army Medical Materiel Development Command
ATTN: SGRD-RMI-S Fort Detrick, MD 21702-5012.

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1. Introduction

The U.S. Army Harry Diamond Laboratories (HDL) was requested by the US Army Medical R&D Command to develop an X-Ray Sighting Device to be used with the X-Ray System, Dental, Miniature (XRSDM), for making medical x-ray images in the field. This sighting device would replace the dental collimator used in the portable dental x-ray set. It was termed the medical collimator.

2. Requirements

The requirements for the medical collimator evolved over a period of months. A summary of the requirements is given in Appendix A.

3. Concept Design

Early concepts and approaches for the medical collimator are described in Appendix B. The listed concepts included the use of optics like that in a camera viewfinder, the use of projected images such as a box or "x" on the film plane, the use of a lightweight extendable mechanical frame to indicate beam locus on the film plane, and finally the use of a laser or combination laser/optical sight. The latter approach was selected for study.

A preliminary design of a laser/optical sight, was proposed and evaluated in July 1991. This design, documented in Appendix C, worked by projecting two red laser dots on the center of the film plane such that the two dots would join into one dot at the center of the film plane when the HDX was at the correct source-to-image distance (SID). The design had merit but was not used because a subsequent clarification of the requirements showed that the need was to indicate the perimeter of the x-ray beam at the film plane, not to locate the center of the x-ray beam. Also, the design had the disadvantage that it required a large separation between the two LDMs to get sufficient horizontal parallax so that the correct SID could be indicated. This made the device bulky. It also required significant vertical parallax correction, which would cause center-location errors at at least two of the three SIDs, and it allowed for only an indirect link between x-ray beam and pointer beam orientation, since both were part of separate assemblies. Hence, another approach was considered necessary.

4. Concept Selection

The configuration ultimately selected was simpler than the one above, and resulted in a more compact device. This concept enabled the source/collimator combination to meet the 21-CFR requirements by projecting a red laser dot on each of the four corners of the target film cassette such that the correct SID is obtained to within 2% accuracy, and the x-ray beam was located inside the film perimeter within the required tolerance of 2% of the SID. The proper SID and aiming are obtained when all four of the laser dots, or when any three of the four dots, are visible (unobstructed) on the film cassette corners. It is sufficient if only two dots are on the film, provided they are positioned on opposite corners (diametrally opposite) of the film cassette. Locating dots on only two adjacent corners leads to possible ambiguities about where the x-ray beam is going. Features of the design are described in the next section, and drawings of the hardware are given in Appendix D. The device was developed according the plan given in Appendix E.

5. Device Description and Design Notes

The central feature of the medical collimator is the x-ray collimator horn, of rectangular cross-section, made of approx. 0.2" aluminum plate. This horn limits the x-ray beam, which starts at the HDX as a beam subtending a 30-degree solid angle, to a rectangular cross section which will meet 14x17 film at 40" SID, 10x12" film at 29" SID, and 8x10 film at 24" SID. Across diagonals, the x-ray beam still subtends the full 30 degrees. Given the small incidence angles of the x-rays, the aluminum plates are able to absorb the x-rays sufficiently without using a lead (Pb) layer and composite construction.

The horn is approximately 4" long, and supports the four laser diode modules (LDMs) used to project the aiming beams. Locating the LDMs directly on the x-ray collimator keeps parallax correction to a minimum and creates a direct mechanical link between the things indicating (LDMs) and the thing indicated (x-ray beam position). Additionally, the horn also acts as a heat sink for the LDMs, each of which dissipates 0.9 W of heat when operating.

The laser diode modules emit red light at 670 nm (visible, red). They are class II (eye safe), rated at 1mW output power each. System power is controlled by an electrically programmable memory (EPROM) and circuit. Currently, settings of the circuit allow beam-on for 10 seconds maximum, followed by a 10-second delay before beam-on again. This fifty-percent duty cycle promotes eye safety and reduces battery drain and heat buildup. The duty cycle or delay times can be adjusted easily by reprogramming the EPROM.

The medical collimator mates with the HDX prototype Source Unit made by Kevex using the same threaded attachment points and mounting face used by the dental collimator. The device is held to the HDX using four captive thru-bolts threaded into these attachment points. As these bolts are tightened, their heads draw up against the housing cover, loading the housing in compression and securing the collimator to the HDX.

The HDX source x-ray tube collet was actually the starting datum for design of the interface plate and other features of the medical collimator. Designing out from this feature assured centering and coaxiality of the collimator over the x-ray source.

The "interface plate" integrates the entire design. Its x-ray window conducts the x-rays into the collimator, while the machined collar locates the collimator accurately over the x-ray tube collet. The flat back surface of the interface plate mates with the HDX front end the same way the dental collimator does. The interface plate then precision locates the horn/laser assembly over the x-ray window, and also supports the power control electronics and the housing (cover) and switch assembly.

The housing was constructed of .063 aluminum sheet, selected for strength and durability in a field environment, and capable of supporting the load applied by the four through-bolts. Having the same cross section as the HDX, and being about 5" in length, the device will fit in the carry case with the HDX (but the foam padding must be changed).

The power control circuit design and logic is elaborated in Appendix F. Design specifications and general description of the laser diode modules are given in Appendix G.

A difficult part of the design is the LDM positioners, mounted on the x-ray horn. These positioners must at the same time a) be easily adjustable, and b) retain a given setting under various thermal and handling conditions. It is expected that this part of the overall concept will evolve some in the next iteration of the design.

There is potential for lightening the overall design in a future production design, through optimization of many of the metal parts, or replacement of metal parts by plastic ones.

This unit was physically designed around the Kevex HDX, but many of the design concepts are transferable to a different source unit.

6. Summary

A medical sighting device prototype was developed for the HDX which indicates x-ray beam position and SID on standard film cassettes. The device collimates the x-ray beam into a rectangular cross section subtending 30 degrees across the diagonal, and uses four low-power laser beams to indicate the perimeter of the x-ray beam at any distance, and the correct SID on three standard film sizes (8 x 10, 10 x 12, and 14 x 17), by matching the laser dots with the film cassette corners. The present device is battery powered and consumes less than 5 W of power; it fits in the carry case with the HDX and attaches to it directly without any adapters, etc. The presented unit was physically designed around the Kevex HDX, but many of the design concepts are transferable to a different source unit.

7. Recommendations: proposed changes to the medical collimator are itemized below, based on evaluations to date of the first engineering prototype, and changes in the requirements:

- increase power of each LDM from .5 mW to 1.0 mW
- power the collimator from the 24 Vdc supply in the HDX Power Control Assembly (eliminate the internal battery); use Mil Std connector tee.
- cover x-ray beam horn opening and laser beam port holes with a sealed polycarbonate window (to keep out debris)
- eliminate corner gaps between backplate and housing corners
- fabricate bore-sighting device for adjusting laser-beam path
- incorporate feature to maintain at least a 7" (178mm) minimum distance between the x-ray source and the patient.
- reduce mass and reduce number of fasteners where possible
- the requirement for a tape measure to indicate the SID is eliminated
- provide a means to guide the through-bolts into their blind holes
- improve method of positioning LDMs

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Appendices

Appendix A: Memorandum, Requirements for HDX Medical Collimator, 13 December 1991.

Appendix B: Collimator and Sight for Medical Imaging Using HDX, Proposed Concepts, 3 July 1991.

Appendix C: Medical Sighting Device for HDX, Preliminary Concept Description, 22 July 1991

Appendix D: Drawings of Sighting Device Hardware, Completed February 1992.

Appendix E: Work Breakdown Structure for Medical Sight Development Task, 6 December 1991.

Appendix F: Power Control Circuit for HDX Medical Collimator

Appendix G: Specifications of the Laser Diode Modules

Appendix A

(of Interim Report)

Memorandum, Requirements for HDX Medical Collimator, 13 December 1991.

SLDHD-TA-MS 13 December 1991

MEMORANDUM FOR James L. Beard, Supervisor, Mechanical Systems Branch

SUBJECT Requirements for HDX Medical Collimator

1. Our branch is designing a prototype collimator and sight for medical x-ray imaging using the HDX (hand-held dental x-ray, source unit). Several concepts have been examined, including one using low-power visible lasers. As the low-power laser approach was taking shape, it became apparent that more clarity was needed on the medical and logistical requirements for the collimator. Consequently, I met with Lloyd Salisbury of USAMMDA and LTC Vandre of USAIDR, at Fort Detrick on Tuesday 30 July 1991, to go over a list of possible requirements, in order to pare down and prioritize the list. The result was the following:

2. <u>Required</u> The medical collimator/sight:

a. Using a single collimator cone (rectangular cross section with 30 degrees arc across diagonal), make exposures of 14 x 17" film at 40 inches SID, and of 10 x 12 and 8 x 10 films at appropriate SIDs, such that the 21-CFR requirements are observed. The 21-CFR requires that x-ray field does not exceed any edge of the image receptor (film) by more than 2 percent of the SID.

b. Must provide a positive indication of the SIDs. More than one method may be possible, but at minimum a retracting tape measure or similar distance indicator must be provided and must be integral to the collimator/sight.

c. Must indicate film perimeter by showing the location of at least one set of diagonal corners of the collimated x-ray beam.

d. The HDX and medical collimator should be operable with the long axis of the film (and of the collimator) either vertical or horizontal.

e.The HDX with medical collimator must be operable hand-held or tripod mounted, including pointing vertically down upon patient and film.

f. Must have the potential for rugged design.

g. Must be lightweight. Under 5 lbs. could be considered lightweight.

h. Is intended to be powered via jumper from the HDX power supply. However, demonstrator versions can have their own battery power.

i. Operation of the collimator and sight must present no visual hazard to operator, patient, or bystander. The visual hazard may be met by supplying protective goggles or instituting simple procedures.

j. The dots showing x-ray beam perimeter must be visible in both darkened room and direct sunlight. It would be permissible to add white tape or reflective tape to film cassette cases for increased visibility of laser beam dots.

3. Desired or Anticipated:

k. The collimator will fit in the same carry case with the HDX and power supply. With the medical sight it becomes a "medical kit." A dental kit consists of the HDX source unit with the existing 20 degree collimator.

l. The collimator will attach to HDX using the threaded hole pattern of the Kevex unit.

m. The collimator will be simple to operate.

n. The sighting laser illumination will have at maximum a 50% duty cycle, with maximum uninterrupted illumination of 10 seconds after a single button press.

o. The sight should not badly affect the mechanical balance of the hand-held dental x-ray when the two units are joined.

4. Not Required:

p. Indicating the center position of the x-ray field on the film may be useful but is not necessary.

q. The collimator need not be self-powered or rechargable. It is planned to be powered with a jumper from the HDX power supply, since the sight is only useful with the HDX and is not useful if the HDX has insufficient power.

r. Quick-attach capability to the HDX is not required. The medical collimator/sight need be no easier to attach to the HDX than the dental collimator (i.e., five minutes).

s. The collimator is not required to display or indicate x-ray "technique" chart.

5. Further work on the HDX medical collimator will incorporate this clarification and prioritization of the requirements. The result may be a simpler approach than we have previously discussed.

Charles H. Robinson
Mechanical Engineer

Appendix B
(of Interim Report)

Collimator and Sight for Medical Imaging Using HDX, Proposed Concepts, 3 July 1991.

COLLIMATOR AND SIGHT FOR MEDICAL IMAGING USING HDX 3 July 1991

Proposed Concepts:

1. Optical Sight

a. Optical sight, using camera-like split-image optics

Pros:
- uses ambient light, no power required.
- split-image optics are well understood;
- can provide all the needed information, i.e, distance, orientation, and centering.
- compact, lightweight.

Cons:
- fragility of optics (shock, vibration, moisture, dirt)
- cost to develop specialized optics;
- sighting is from off-axis, introducing parallax error—requires very exact adjustment for different target distances;
- operator is required to place head next to HDX to do sighting (awkward);
- sighting is painstaking and requires good light, requires a good "eye" to accomplish sighting and distance verification;
- difficult to do sighting with HDX in some orientations (especially pointing straight down);
- absence of pattern or feature on the film cassette to assist sighting and distance verification with split-image.

b. Mechanical version of the optical sight—e.g., adjustable "goalpost" frame with crosshair sight for aiming and distance verification.

Pros:
- uses ambient light.
- requires no power.
- may be easy to make for a limited number of settings (40" and 60" settings)

Cons:
- mechanical sight easily damaged;
- bulky
- requires a good "eye" to accomplish sighting and distance measurement—sighting is painstaking and requires good light;
- requires that each operator sight in exactly the same way
- difficult to do sighting with HDX in some orientations (e.g., pointing straight down) because the operator must get behind the HDX to see through the sight.

2. Projected-image sight:

a. Projected Icon (e.g., box or cruciform center) using light source, mask, and lens.

Pros:
- good for centering and orientation information
- simple approach
- lightweight, compact
- aiming can be done with HDX in any orientation
- could adjust brightness for conditions to save battery

Cons:
- does not provide film distance verification directly, requires that film distance be measured some other way
- projected light image may not be visible in bright light or against some backgrounds
- expect large power draw and possible frequent bulb/battery replacement.

b. Low-power laser sight, laser pointers and/or line-generating prisms create centering image (cruciform, dot, or circle); combine with tape measure or dual images to indicate film distance.

Pros:
- good for centering and possibly for orientation information
- aiming icon highly visible in most conditions, with potential for visibility even in direct sunlight
- low power requirements
- lightweight and compact
- aiming can be done with HDX in any orientation, no necessity to sight through an awkward mechanism.

Cons:
- may not provide film distance verification (without optics), requires that film distance be measured some other way
- may pose eyesight hazard, due to reflections and projecting laser light into unknown background
- requires power
- possible high cost for materials;
- unknown potential for ruggedness.

3. Extendable Frame: flexcord tent expandable frame.

Pros:
- shows correct distance and exposure frame
- when properly assembled, hard to use incorrectly
- possibly inexpensive in quantity.

Cons:
- frame may sag over the 60" distance

- cumbersome to change back and forth between the 40" and 60" film distances
- frame will interfere with the patient, and may be unpleasant to patient
- if made of metal, problem of x-ray scatter.

4. Combined Optical/Laser Sight: using laser lines or cruciform on target, use optics to verify distance to target and "frame" correctly.

Pros:
- laser icon(s) indicates target center
- possible split horiz/vert laser lines form symmetrical cross at correct distance. Dual settings to cover 40" and 60" targets.
- optical sight provides distance verification and orientation (framing)
- low power, uses minimum projected light
- makes use of ambient light
- can be operated in dark (using laser) or in intense light (using optics)
- compact and lightweight
- simplest operation is to use laser to "center" and tape measure for distance

Cons:
- fragility of optics to shock, vibration, moisture, dirt
- high cost to develop and qualify optics
- operator is required to place head next to HDX (awkward)
- difficulty of splitting laser light into horiz/vert lines

Appendix C
(of Interim Report)

Medical Sighting Device for HDX, Preliminary Concept Description, 22 July 1991

FOR HDX

MEDICAL COLLIMATOR

22 July 1991
C. H. Robinson
Harry Diamond Labs

General Approach

It has been proposed to use the HDX (hand-held dental x-ray source unit) for making medical size x-ray images (chest, head) in field locations where the HDX may be available and other x-ray equipment may not. At the standard source-to-image distance (SID) of 60" for such images the necessary exposure time for the low-powered unit is excessive, and patient motion is likely to interfere with image quality. Consequently, a design for a medical collimator and sight for the HDX is proposed here which will make it possible to make 14 x 17 inch images at a SID of 40", using a 30 degree collimator angle. Sketches are attached which show the concept. One version of the collimator is conceived for imaging only at 40" SID, another version can be adjusted for use at either 40" or 60" SID. The collimator "cone" is rectangular in cross section to comply with the 21-CFR requirement that x-ray exposure not occur outside film perimeter.

The medical collimator for the HDX allows the operator to locate the x-ray beam accurately on the film by providing both centering and distance indications at 40" source-to-image distance, accurate to within the 21-CFR guidelines. The concept elaborated here involves using a pair of low-power laser diode modules located a known distance apart and angled to the target film plane to provide the centering and distance information needed by the operator.

Design Information

A. The medical collimator is self-powered (battery), rechargable, lightweight, hand-held, self-contained, compatible with the HDX (uses existing threaded attachment points), operable in any orientation, and provides a bright laser dot for high visibility on the target plane in a wide range of ambient lighting conditions. The system uses Class-II (eye safe) lasers and should present no danger to operator or to patient or bystander.

B. Centering: center location of the x-ray beam is indicated by a red laser dot emitted by a low-power laser diode module (LDM) positioned directly under the x-ray collimator cone, and angled upwards to meet the film in the exact center of the x-ray field at the film plane. Reference the sketches. There is a parallax error introduced by the vertical offset of the center-indicating laser module, so a correction is made by tilting the laser module upwards. This "look-up" angle is 3.3 degrees for source-to-image distance (SID) of 40" and 2.13 degrees for SID of 60". A compromise can be achieved at 2.6 degrees look-up angle to give an optimum tradeoff when a single look-up angle must do for both SIDs. At this look-up angle of 2.6 degrees, the centering dot is aimed .45" low at the 40" film plane and .45" high at the 60" film plane. This amount of error is within the 21-CFR guidelines.

using a second low-power laser to project a beam that will exactly overlap the first dot at the correct SID. An incorrect SID will result in the appearance of two dots instead of one. The task of the operator is to change the SID to make the center dot and the side dot coincide. If the HDX is too close to the film plane, the dot from the side laser will appear to the right of the center dot. If the source is too far away from the film, the side laser dot will appear to the left of the center dot. As long as the centers of the dots are within 4mm of eachother, which is easy to see at the range of 5 feet, then the SID is accurate to within the 21 CFR guidelines (2% of SID). A variation of this concept is to project a vertical laser line (optically fanned-out dot) from the side LDM, so that the task of the operator will be to make the center dot and the line coincide. This approach makes it more definite which way to vary the SID to get the proper distance, since the line can be differentiated from the dot (e.g., the line to the right of the center dot means the SID should be increased, and the line to the left means the SID should be decreased).

D. Medical Collimator Designed for Single Film Plane: a collimator designed for use only at the 40" film plane distance will have a look-up angle of 3.3 degrees for both the center and the side LDMs, and a look-in angle of 7.5 degrees for the side LDM, with a separation distance of 4.76" between the two laser modules. A collimator designed for use only at the 60" film plane distance will have a look-up angle of 2.13 degrees for both the center and side LDMs, and a look-in angle of 7.5 degrees for the side LDM, with a separation of 7.4" between the two lasers. The 40" collimator is more compact than the 60" collimator.

E. Medical Collimator Designed for Dual Use at 40" and 60" Film Planes: a collimator designed for dual use has a two-position adjustment which sets the side laser "look-in" angle to either 11.5 degrees, for distance indication at 40" SID, or 7.5 degrees for distance indication at 60" SID. The look-up angle is set at the tradeoff value of 2.6 degrees.

In summary, the key dimensions are as follows:

	40" Only	60" Only	Dual 40" and 60"
Laser Source Separation Distance (Single Side)	4.76"	7.4"	7.4"
Look-In Angle (Horizontal Aiming)	7.5	7.5	11.5 and 7.5
Look-Up Angle (Vertical Aiming)	3.3	2.13	2.6

Design Features:

- access panel on side of collimator permits battery pack replacement

- device has sheet aluminum enclosure, approx. 0.030" thick, and double thickness on bottom portion for stiffness.

- expose film with long axis horizontal by rotating whole HDX and attached collimator by 90 degrees, or consider a way to make attachment work for 0 and 90 degree orientations.

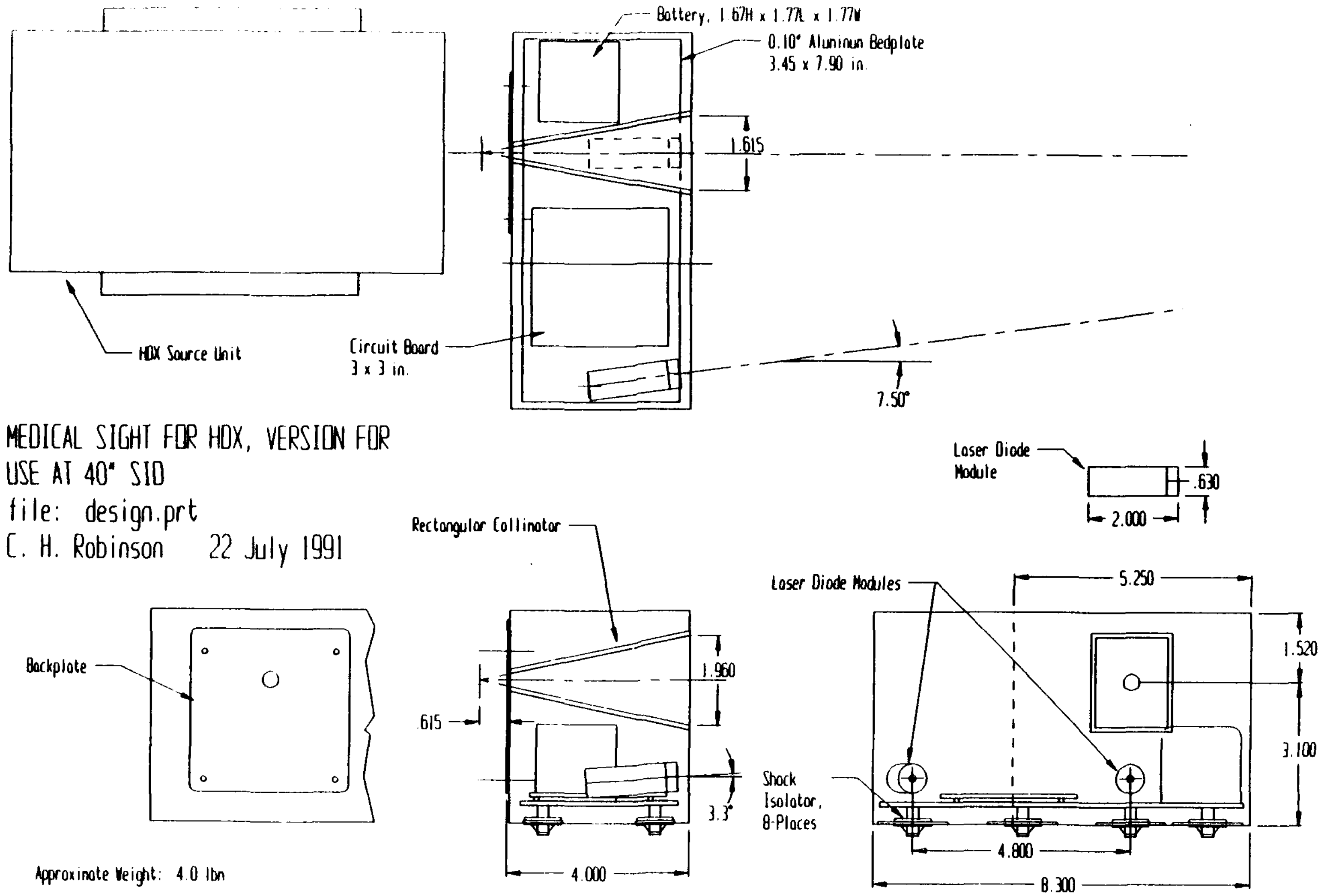
- design a special backplate to allow quick attachment and removal, while also giving accurate positioning of the collimator relative to the HDX. Consider having four t-posts and slots, with a pin-in-hole locator/lock.

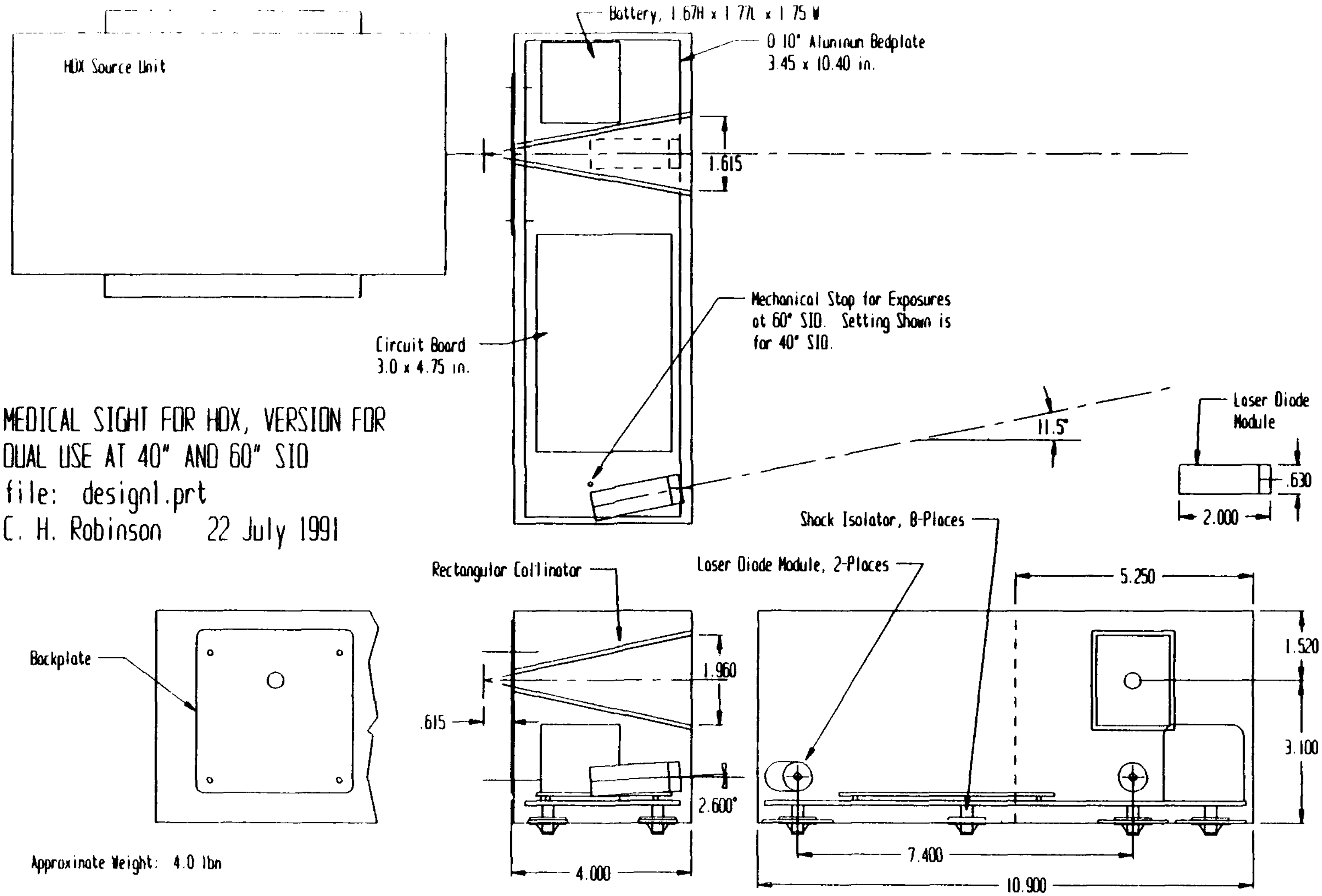
- the device must have its own 30 degree collimator built in.

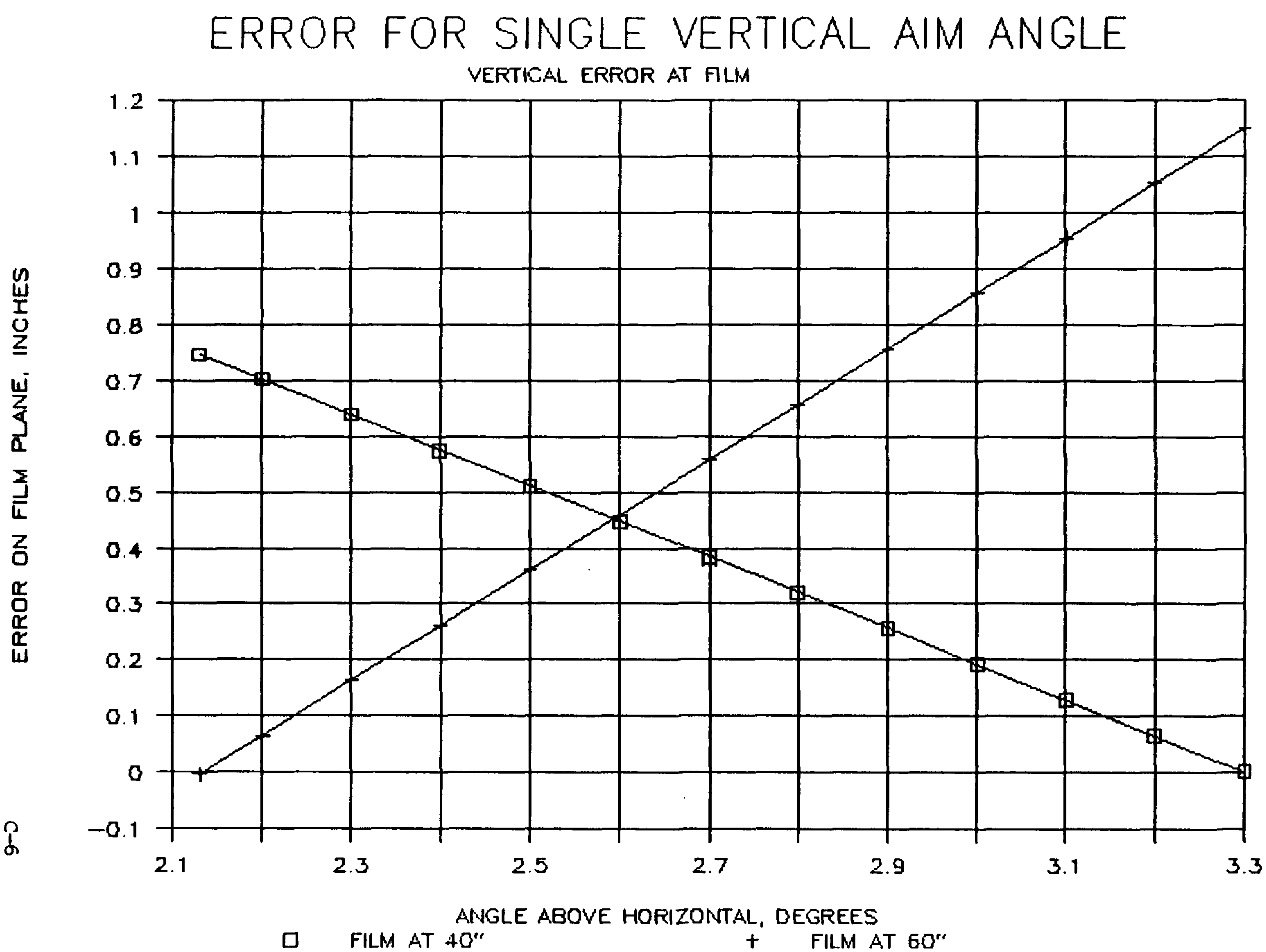
- batteries are located as shown to balance the device.

- shock isolators float the "optical table" to protect alignment of laser modules. Problem: lining up optical subassembly with x-ray source. It all may depend on using the backplate as a hard point.

(Reference DESIGN.PRT AND DESIGN1.PRT files) file: design.doc

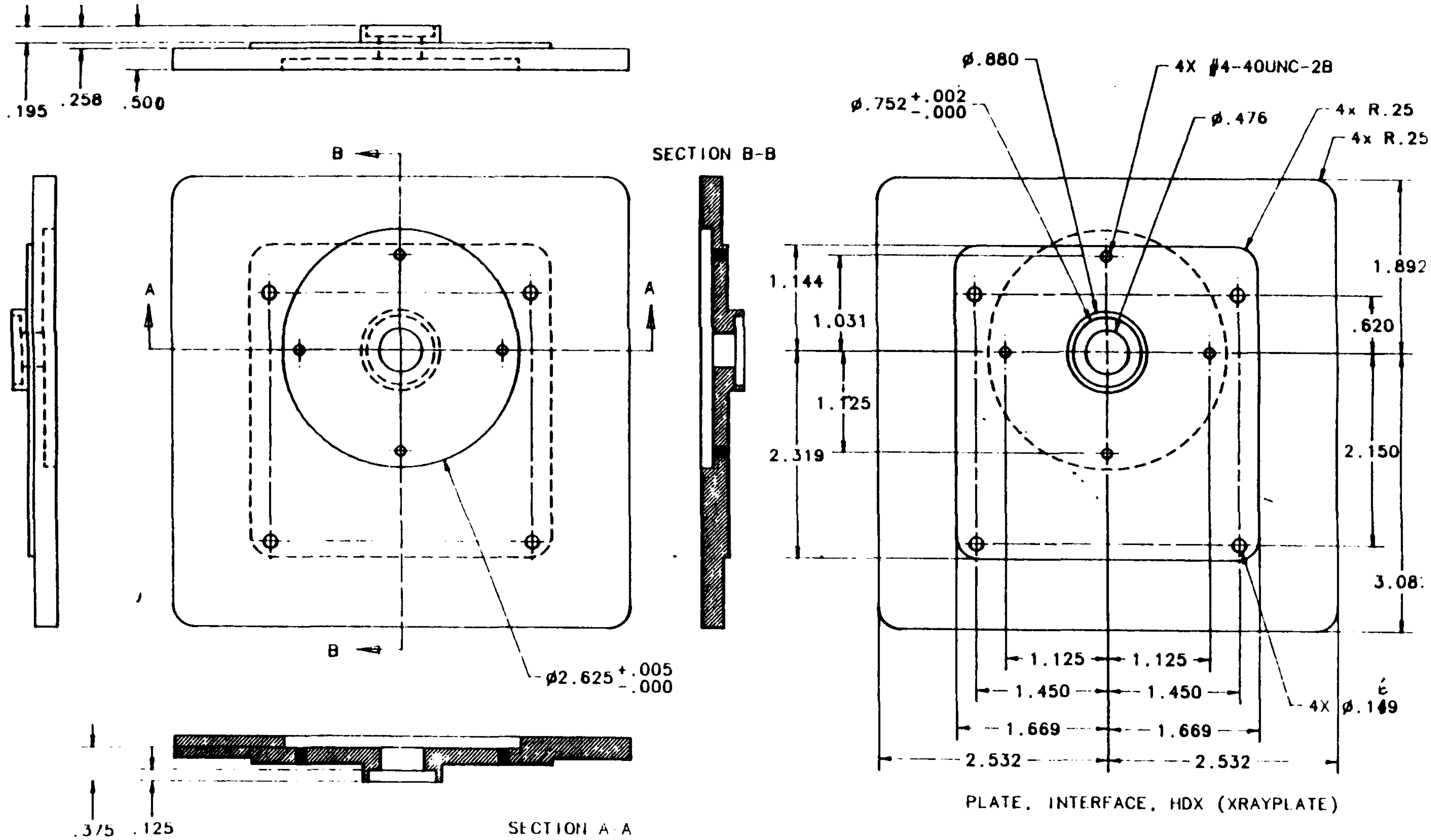

MEDICAL SIGHT FOR HDX, VERSION FOR
USE AT 40" SID
file: design.prt
C. H. Robinson 22 July 1991
Battery, 1.67H x 1.77L x 1.77W
0.10" Aluminum Bedplate
3.45 x 7.90 in.
1.615
HDX Source Unit
Circuit Board
3 x 3 in.
7.50°
Laser Diode
Module
.630
2.000
Rectangular Collimator
Backplate
1.960
.615
3.3°
4.000
Shock
Isolator,
8-Places
Laser Diode Modules
5.250
1.520
3.100
4.800
8.300
Approximate Weight: 4.0 lbn


HDX Source Unit
Battery, 1.67H x 1.77L x 1.75 W
0.10" Aluminum Bedplate
3.45 x 10.40 in.
1.615
Circuit Board
3.0 x 4.75 in.
Mechanical Stop for Exposures
at 60" SID. Setting Shown is
for 40" SID.
11.5°
Laser Diode
Module
.630
2.000
MEDICAL SIGHT FOR HDX, VERSION FOR
DUAL USE AT 40" AND 60" SID
file: design1.prt
C. H. Robinson 22 July 1991
Shock Isolator, 8-Places
Laser Diode Module, 2-Places
Rectangular Collimator
5.250
1.520
3.100
Backplate
1.960
.615
2.600"
7.400
4.000
10.900
Approximate Weight: 4.0 lbn

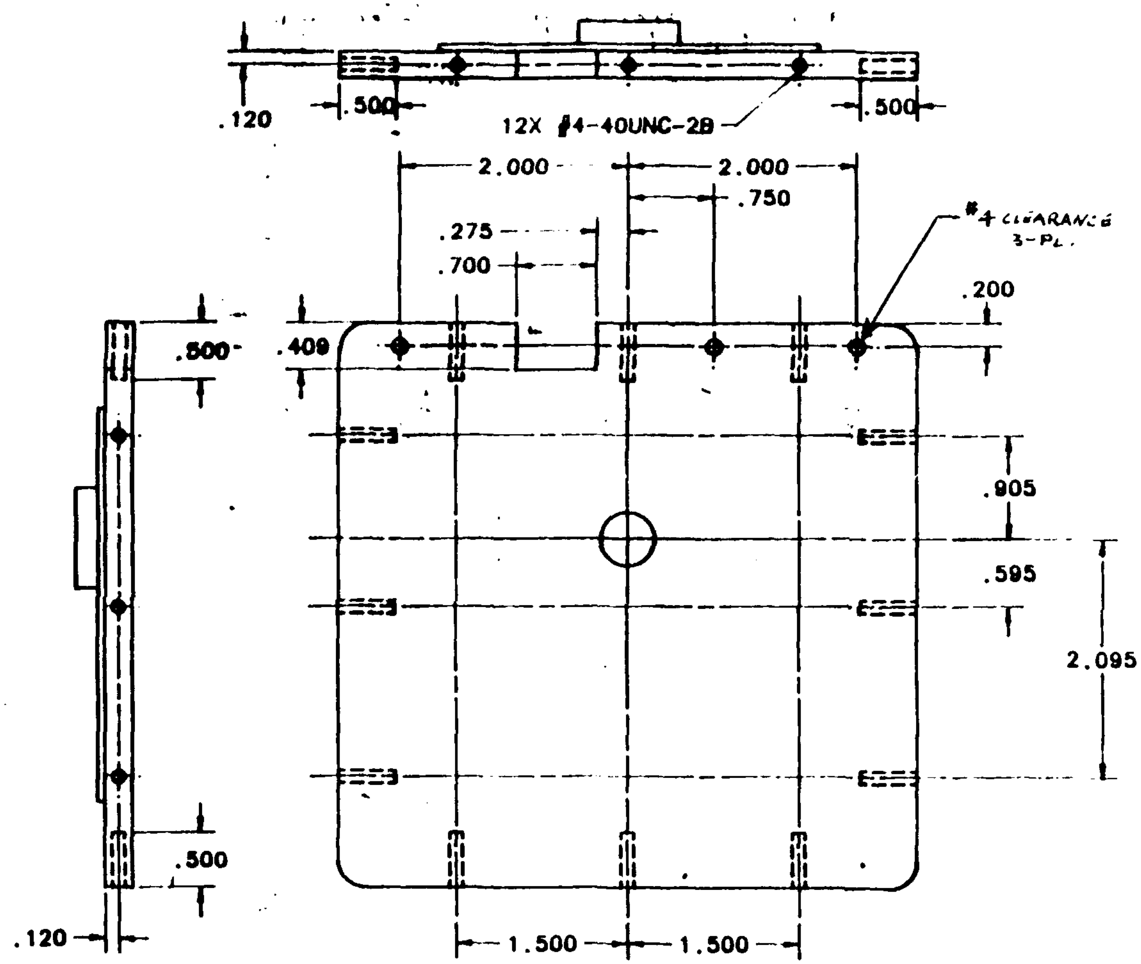

ERROR FOR SINGLE VERTICAL AIM ANGLE
VERTICAL ERROR AT FILM
ERROR ON FILM PLANE, INCHES
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
−0.1
2.1
2.3
2.5
2.7
2.9
3.1
3.3
ANGLE ABOVE HORIZONTAL, DEGREES
□ FILM AT 40"
\+ FILM AT 60"

Appendix D
(of Interim Report)

Drawings of Sighting Device Hardware, Completed February 1992.



PLATE, INTERFACE, HDX (XRAYPLATE)



PLATE, INTERFACE, HDX (XRAYPLATE2)

NOTE:
SOME HIDDEN LINES AND FEATURES HAVE BEEN OMITTED FOR THE SAKE OF CLARITY.

THIS

PAGE

IS

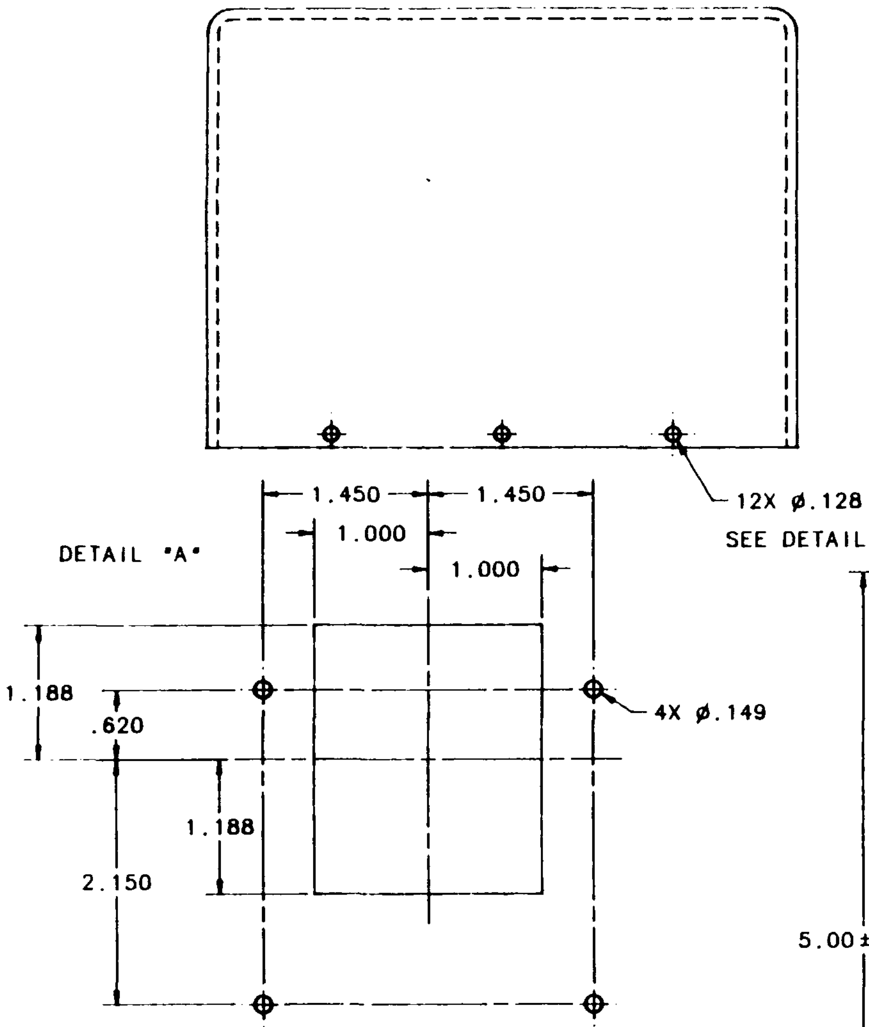
MISSING

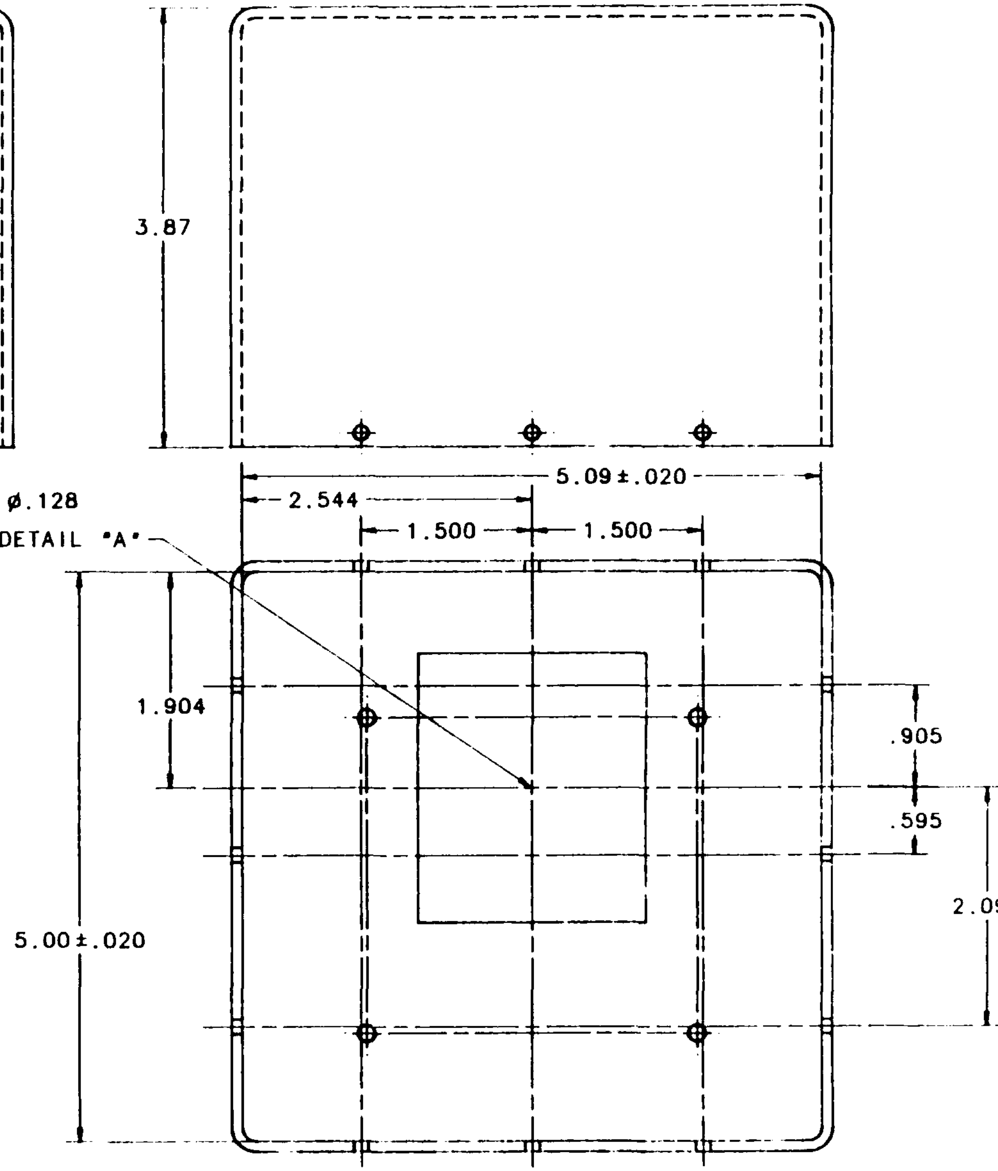
IN

ORIGINAL

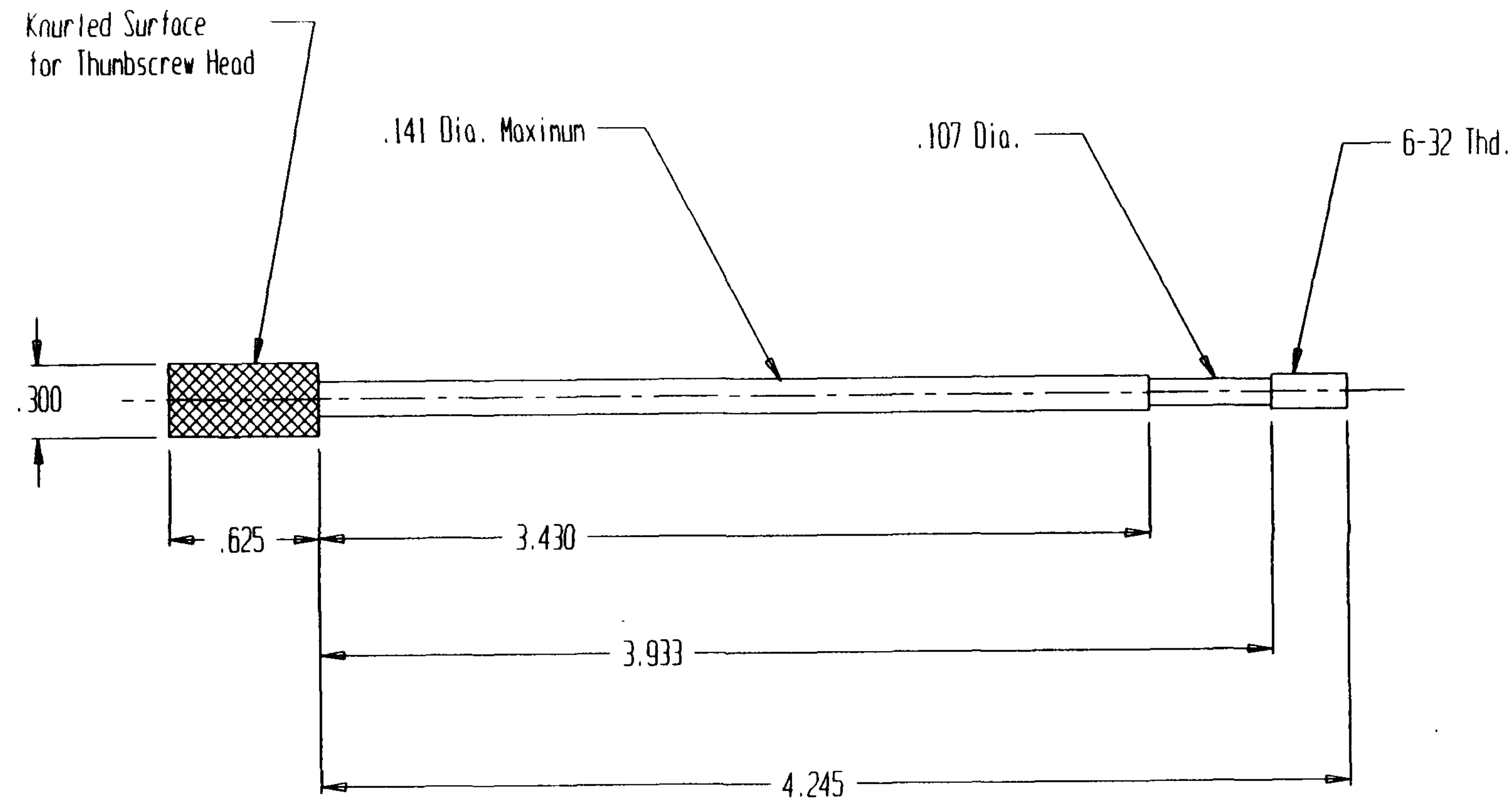
DOCUMENT

D-3





1. MATERIAL: ALUMINUM ALLOY, SHEET STOCK, ~~.034~~ .063 THICK.
2. ALL INSIDE BEND RADII .12 MINIMUM.
3. ALL SEAMS SHALL HAVE CONTINUOUS WELDS OF A SIZE EQUAL TO THE THICKNESS OF THE MATERIAL JOINED. ALL EXTERIOR WELDS SHALL BE GROUND SMOOTH.

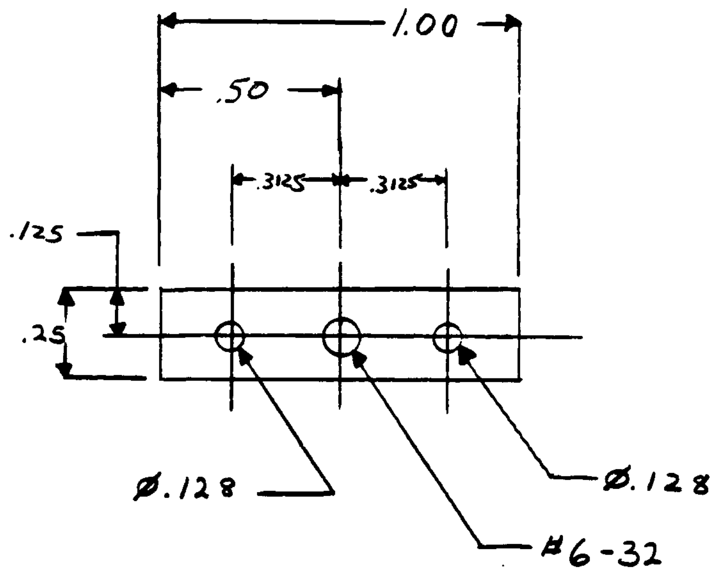


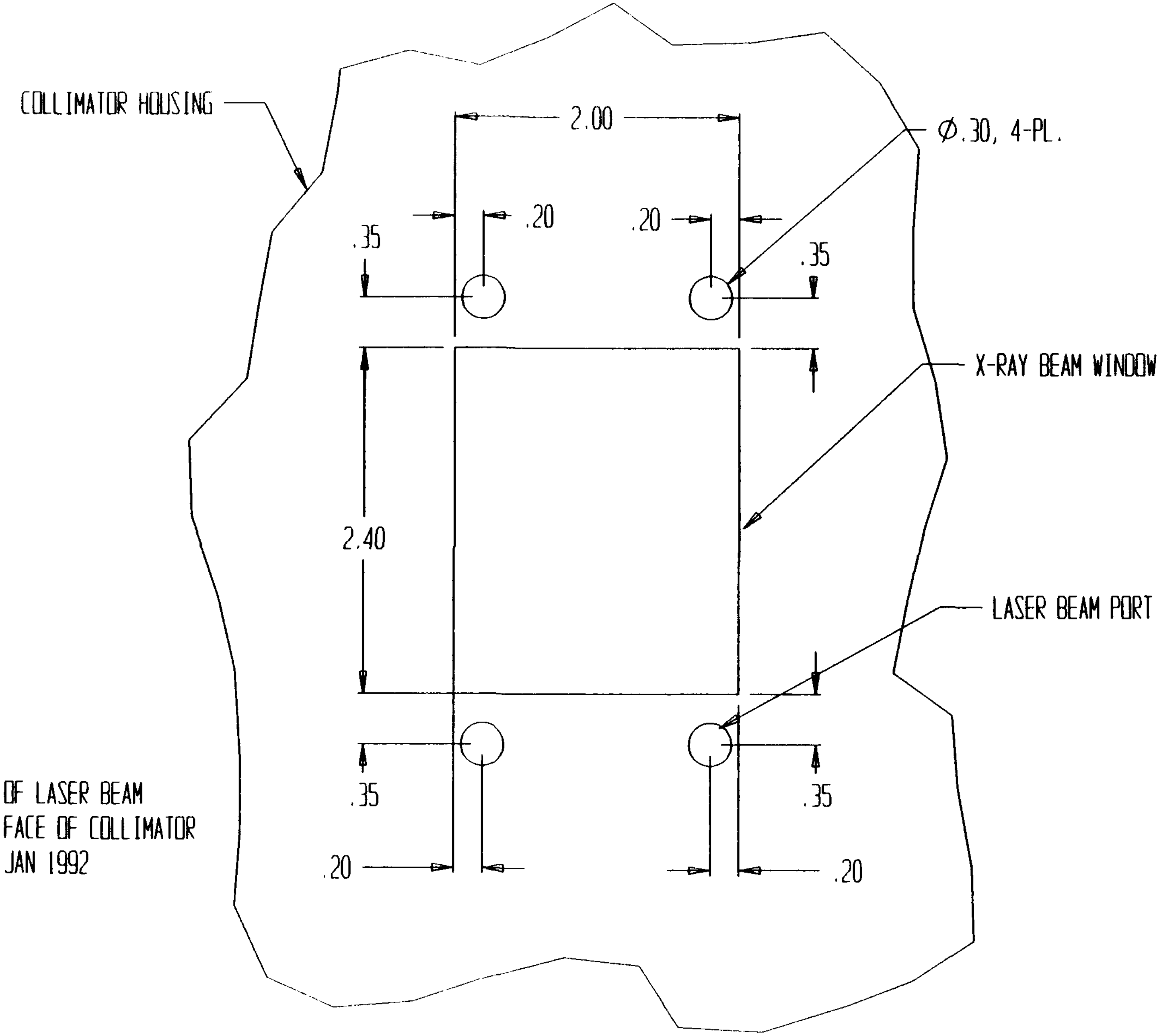
THRU-BOLT FOR MEDICAL COLLIMATOR, 4 EA.
February 1992

1-31-92

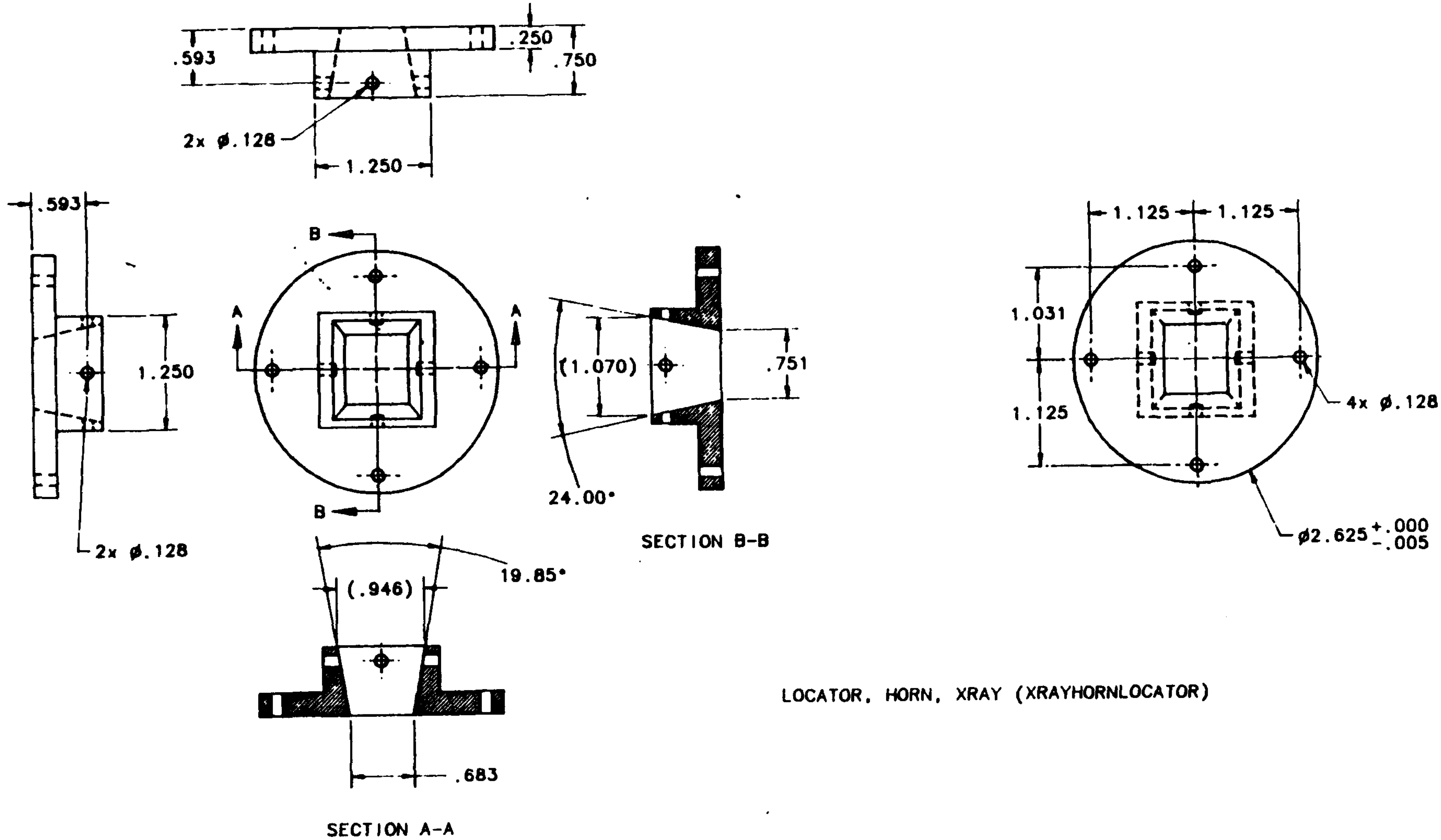
RETAINING BRACKET
FOR THROUGH-BOLTS,
HDX MEDICAL COLLIMATOR

MATERIAL - AL
THICKNESS - .094
4 each.

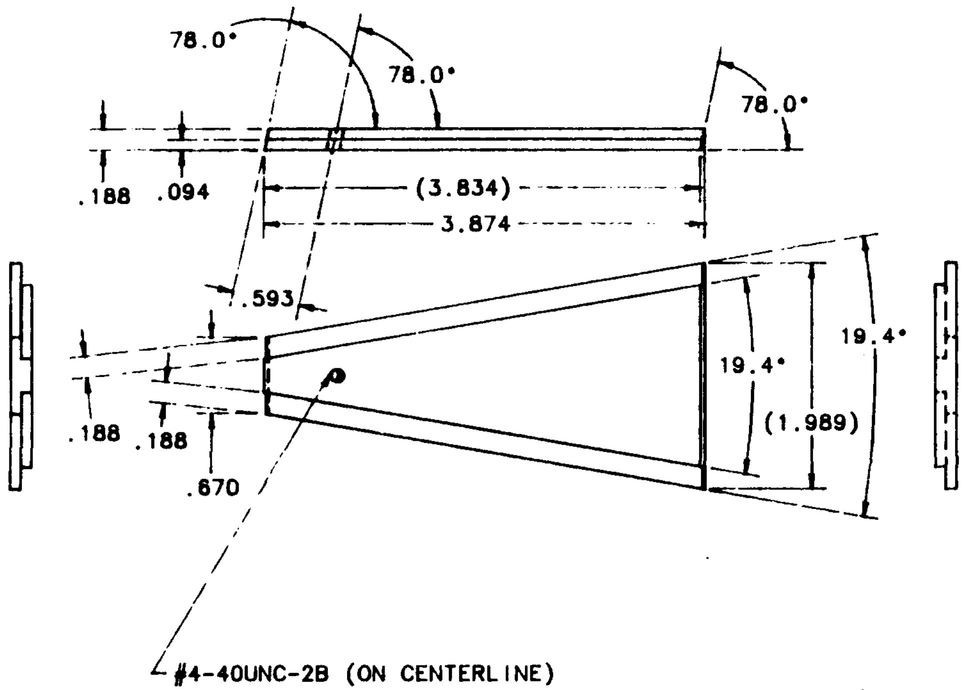




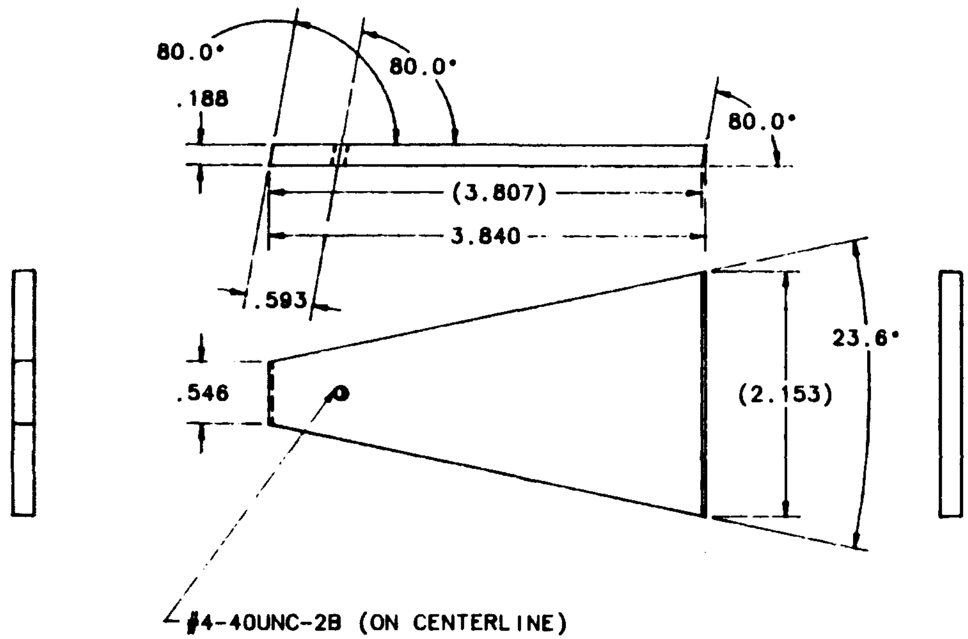
LOCATION OF LASER BEAM
PORTS ON FACE OF COLLIMATOR
HOUSING JAN 1992



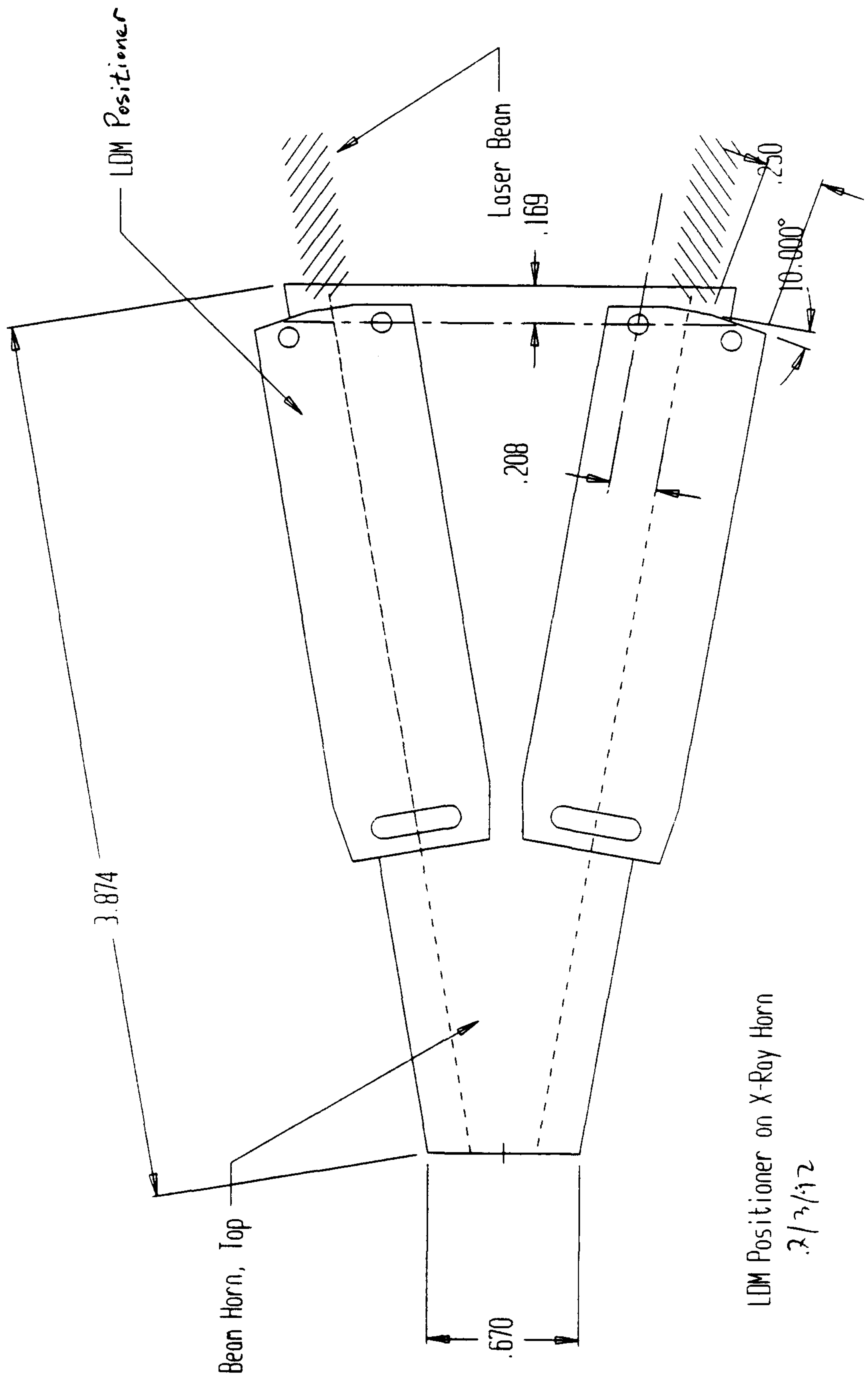
LOCATOR, HORN, XRAY (XRAYHORNLOCATOR)

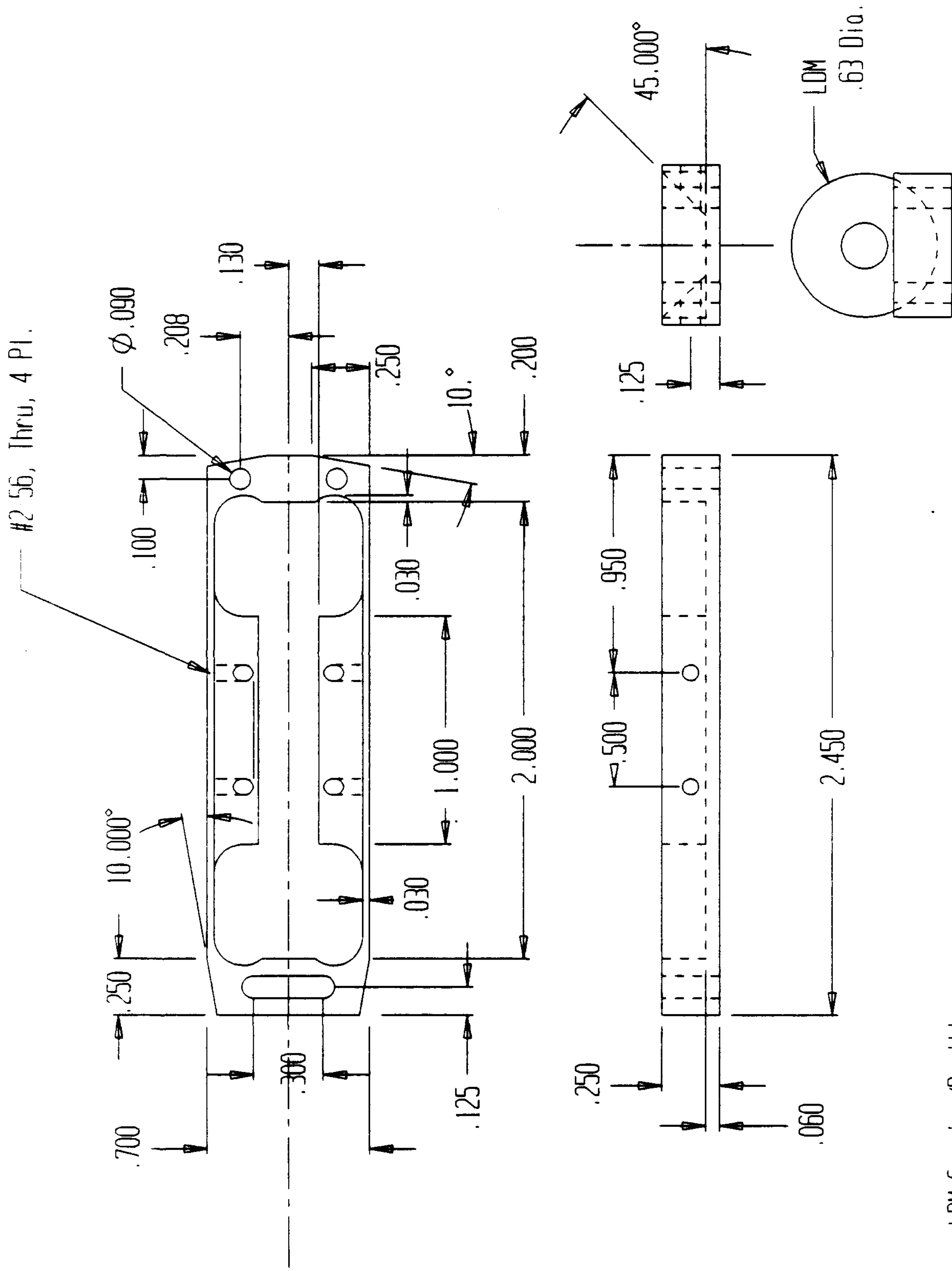


PLATE, TOP/BOTTOM, HORN, XRAY (XRAYTOPPLATE)



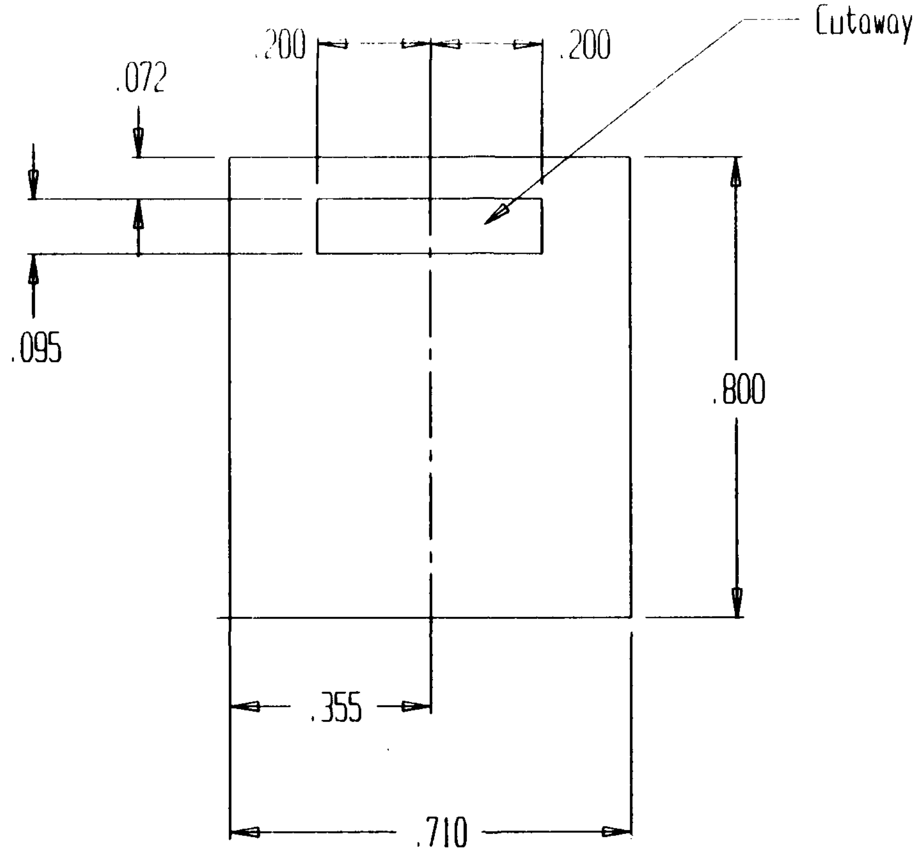
PLATE, SIDE, HORN, XRAY (XRAYSIDEPLATE)


LDM Positioner
Laser Beam
.169
.250
10.000°
.208
3.874
Beam Horn, Top
.670
LDM Positioner on X-Ray Horn
2/3/92

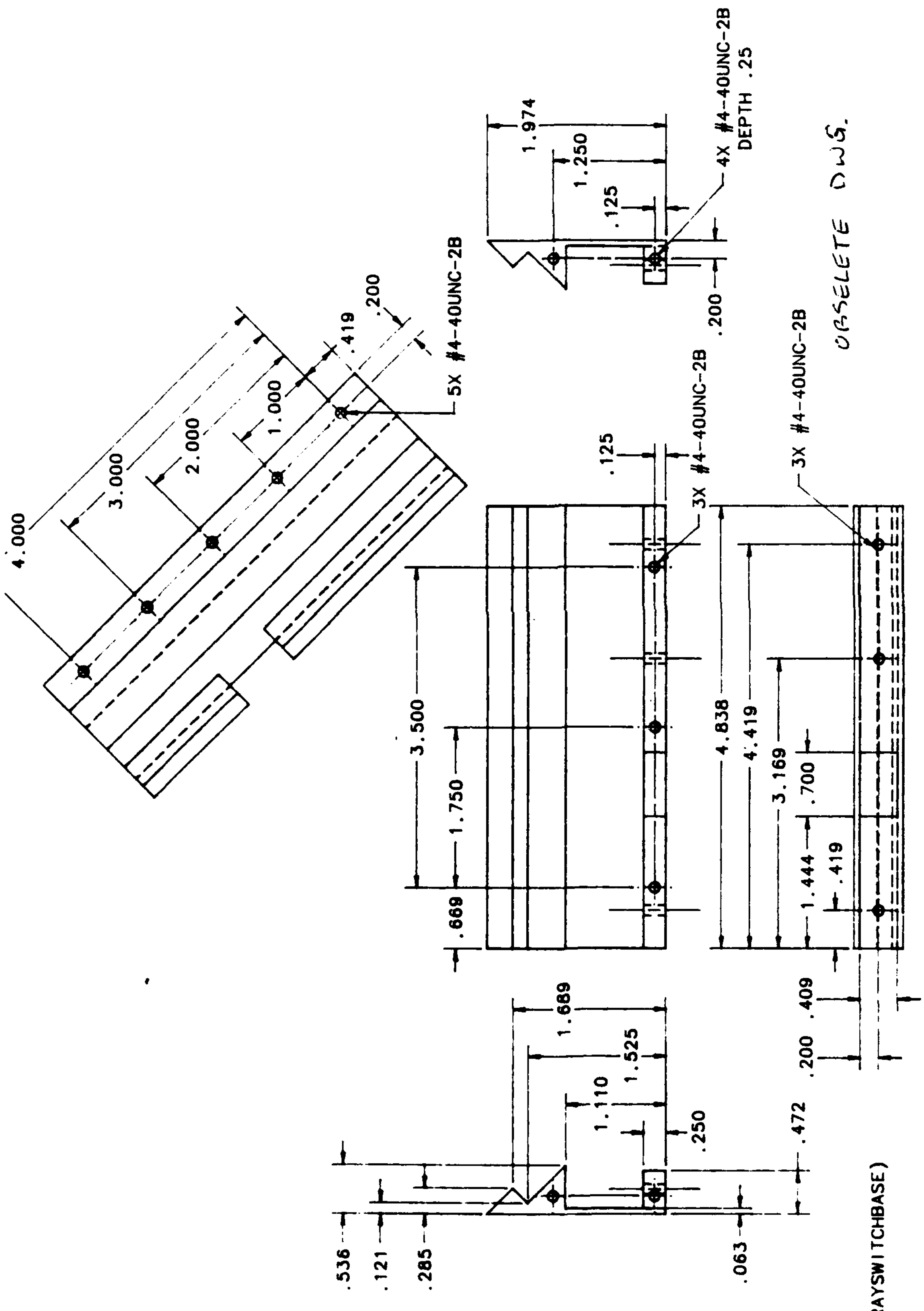


LDM Carrier/Positioner

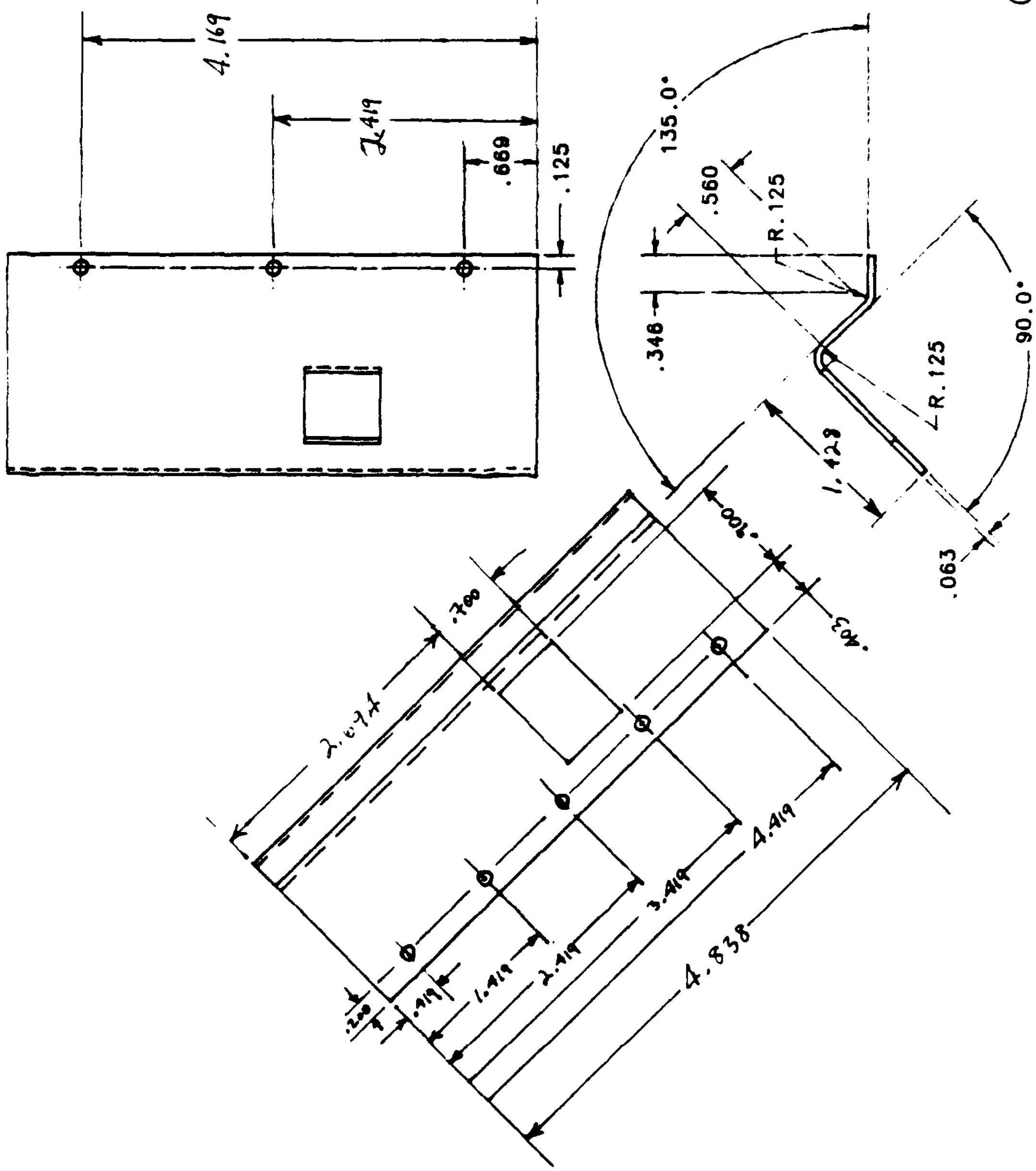
2-3-92



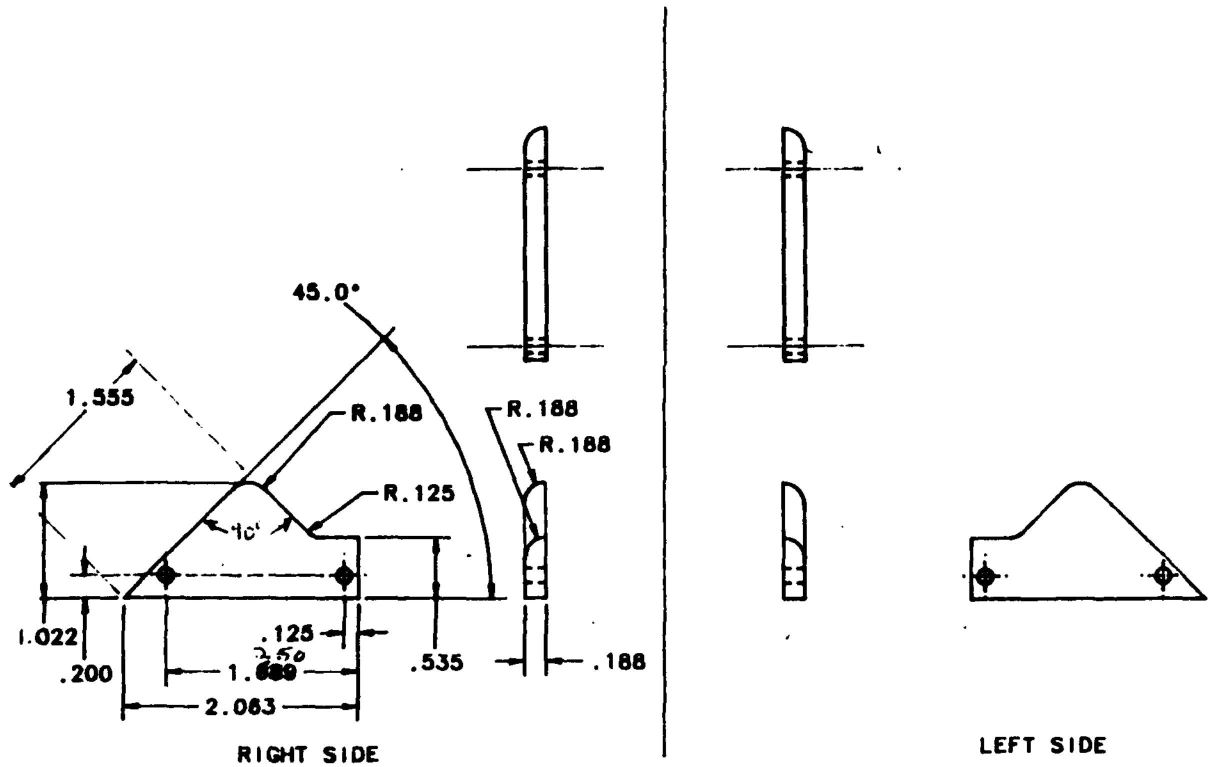
SHIM FOR LDM POSITIONER
Material: Poron Closed Cell Foam, #4701-05-20125-1637
Thickness, .125"



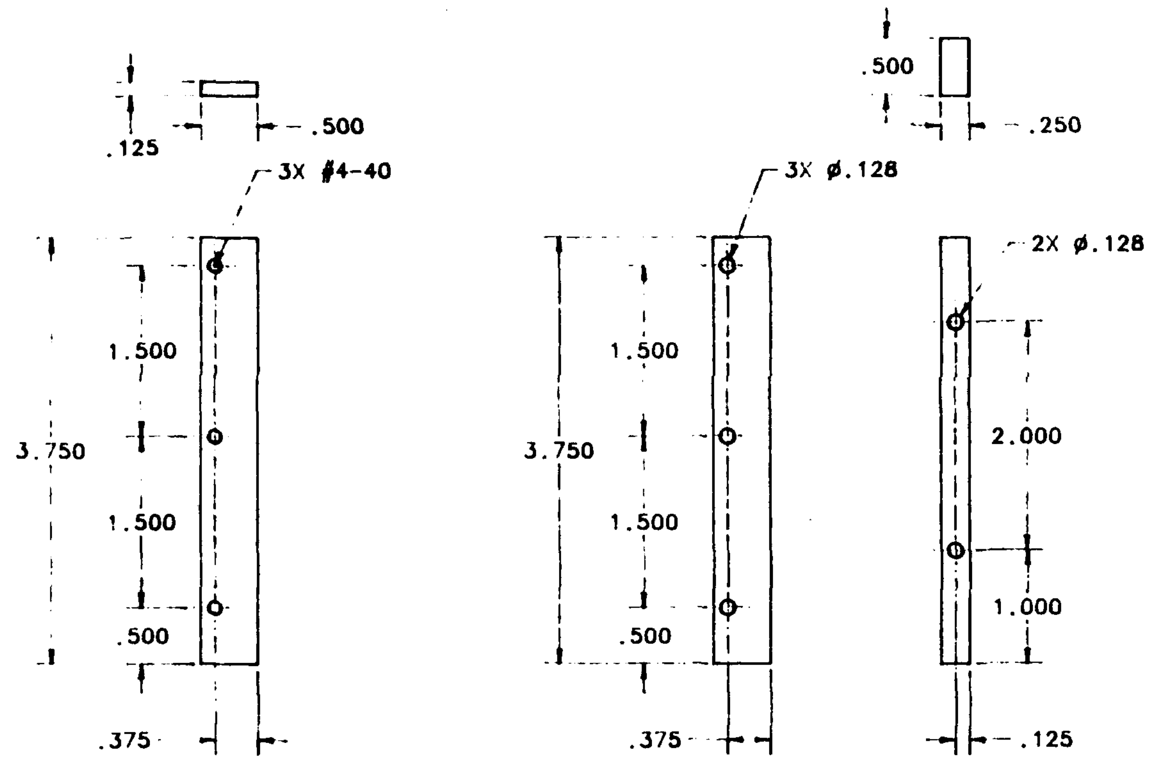
(XRAYSWITCHBASE)



(XRAYSWITCHTOP)



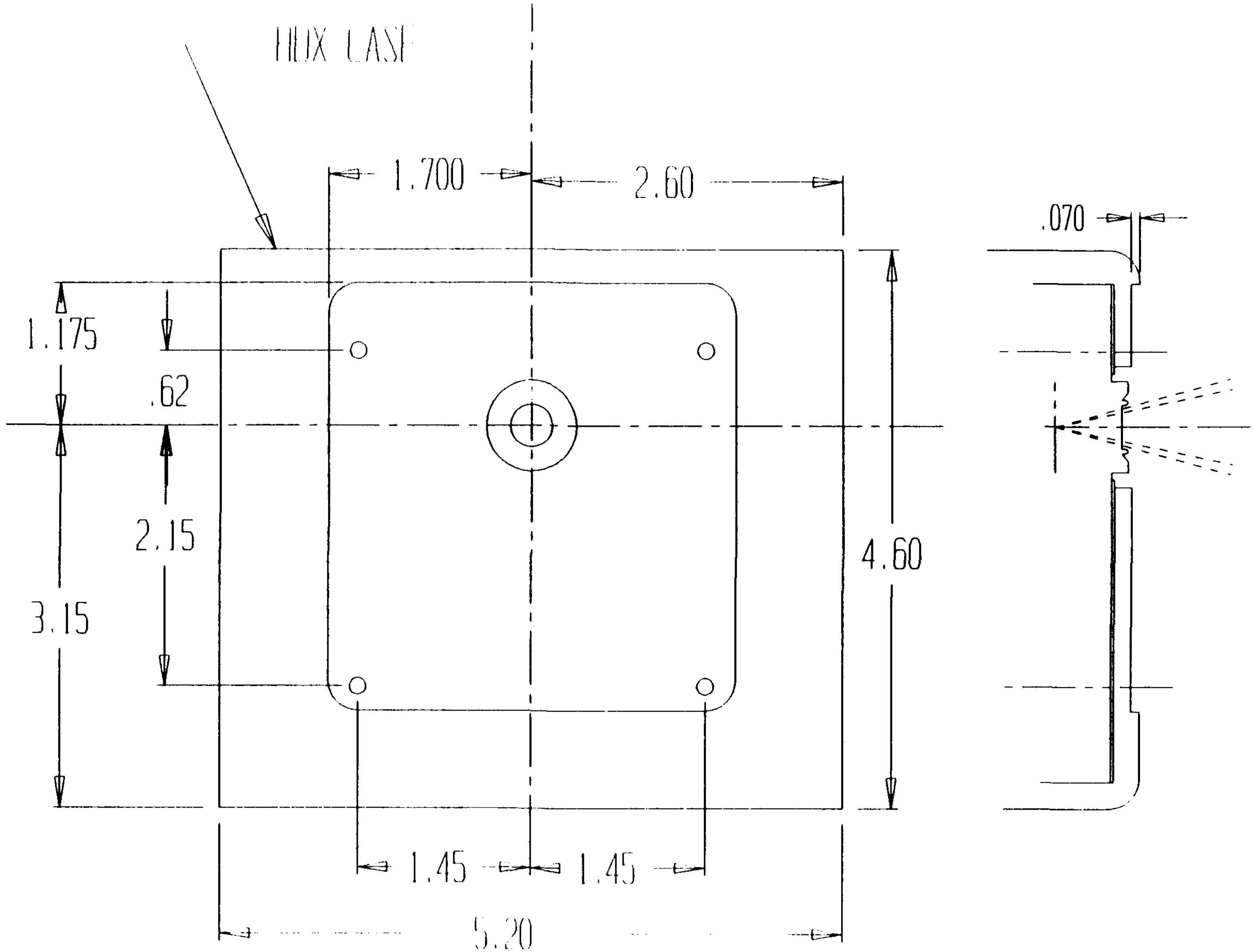
(XRAYSWITCHSIDE)



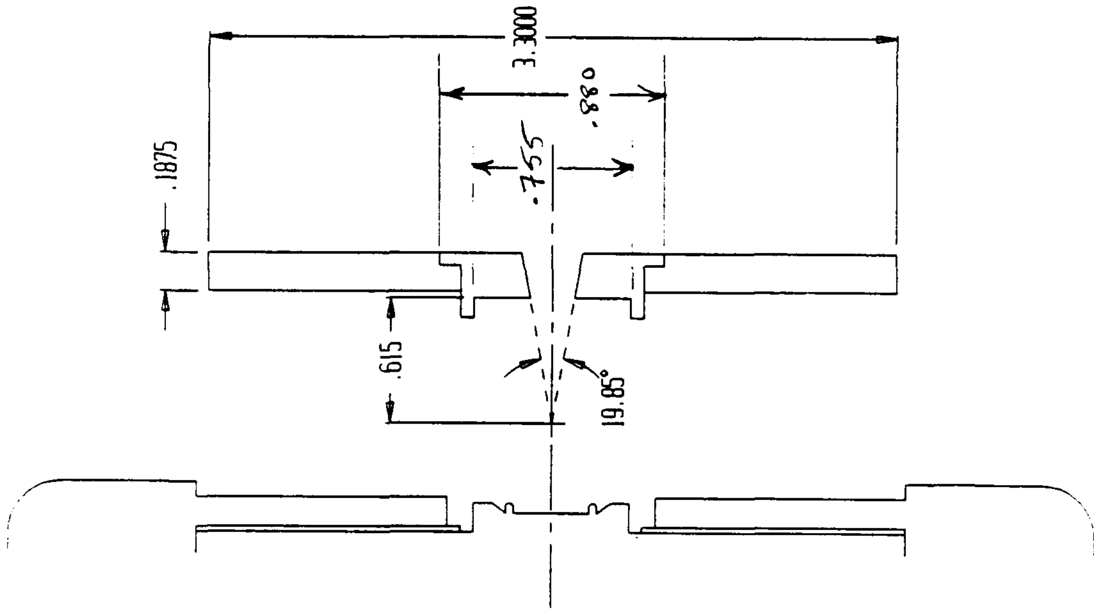
(XRAYPCBOARDPLATES)

MATERIAL: AL
QTY: 1 OF EACH

2/3/92



Measurements Taken From HDX Test Prototype Model PXS7-730EA, P/N 5971-1009.


3.3000
.880
.755
.1875
.615
19.85°

Appendix E
(of Interim Report)

Work Breakdown Structure for Medical Sight Development Task, 6 December 1991.

WBS for Gantt Chart of Medical Sight Development Task 6 December 1991

1. Problem/Task Definition

2. Characterize Optics, Decide Approach
   a. 21-CFR guidelines
   b. functional requirements
   c. weight and size requirements
   d. evaluation of alternative design concepts
   e. selection of design approach

3. Conceptual Design
   a. mechanical
      - structural, including HDX interface
      - optical
      - thermal
      - x-radiation collimation
   b. electronic
      - power, including HDX interface
      - control circuit
      - indicator panel
   c. human interface

4. Hardware Design
   a. mechanical
      - structural
      - optical
      - thermal
   b. electronic
      - power
      - control circuit
      - indicator panel
   c. purchase requisitions

5. First Prototype Fabrication
   a. mechanical
   b. electronic
   c. configuration documentation

6. Bench Demonstration/Evaluation, Design Validation

7. Feature Redesign and Update

8. Fabrication of Additional Units (4 each)

9. Demonstration and Handoff to MRDC

10. Follow-Up and Support.

Appendix F
(of Interim Report)

Power Control Circuit for HDX Medical Collimator

POWER CONTROL CIRCUIT FOR HDX MEDICAL COLLIMATOR 9 December 91

Operating Sequence:

- attach sight to HDX (thumbscrews match existing threaded holes in HDX)

- connect umbilical power to HDX (or insert battery into collimator/sight)

- toggle sight power switch to ON
  . green LED on collimator illuminates for POWER ON condition
  . circuit board receives power
  . circuit checks battery status, if low is shown by red LED on panel
  . power-on timer circuit starts, with time-out set for 10 minutes
  . laser-on toggle switch is energized (made functional)
  . experience constant small current draw on battery/umbilical power
  . system awaits either laser-on toggle or power-on time-out

- toggle laser-on (sighting) switch
  . laser-on LED illuminates on panel when LDMs are powered
  . brief audible tone emitted to indicate laser on, different than HDX tone.
  . circuit board switches power to LDMs
  . start laser-on timer (time-out at 10 sec.)
  . reset power-on timer to zero

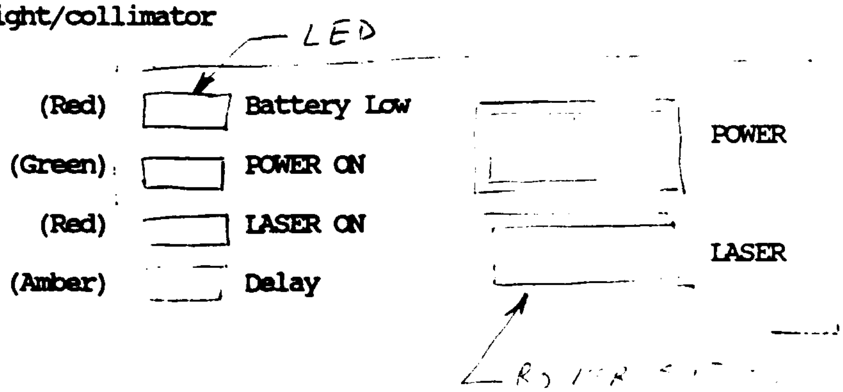
- laser-on time-out occurs
  . removes power from LDMs
  . start 10-sec delay timer circuit (use same circuit as laser-on timer?)
  . amber LED on panel indicates laser time-out delay circuit is active

- laser delay time-out occurs.
  . switch off amber LED on panel
  . restore control to LDM power circuit. LDMs can now be activated at any
    time by another toggle of the laser-on switch.

- the laser-on/delay cycle is repeated as many times as desired or until battery low indicator goes on.

- the 10-minute timer runs out when the laser is not activated
  . no power to the sight/collimator

PROPOSED PANEL LAYOUT



NOTES:

The purpose of the 10-second delay between laser illuminations is threefold: a) converve battery power, b) allow time for heat dissipation from the LDMs, c) promote eye safety through intermitant operation of lasers.

SUMMARY OF MODULES AND FUNCTIONS:

- panel for LEDs and switches
  - . panel switches: power-on, sighting (laser-on)
  - . panel LEDs: one green, two red, one amber
- circuit board(s)
  - . system-on timer (10 minute)
  - . laser-on timer ckt. (10 second)
  - . laser-off timer (10 second—could be same as above)
  - . logic
  - . several power switches, logic activated
  - . battery level monitor
  - . tone emitter
  - . connectors for modularity
- collimator
- laser diode modules (LDMs)
- battery and holder
- housing
  - . HDX interface plate
  - . attachment screws
  - . source-to-image-distance (SID) indicator

Do not permit the LDMs to see more than 5.25 Vdc. Their rated operating voltage is 3 to 5.25 Vdc. They each draw approximately 90 mA.

A single 9V battery is planned for each collimator unit.

Five medical collimators will be fabricated.

SLCHD-TA-MS 15 Jan 92

MEMORANDUM FOR SLCHD-TA-MS (C. Robinson)

SUBJECT: X-Ray Sight Controller, Version 1

1. This is a summary of the work done on the prototype controller module for the Hand-held Dental X-ray (HDX) optical sight. The optical sight is a system of four laser diode modules (LDM's) which are angled outward about the x-ray aperture. These LDM's produce a set of dots corresponding to the corners of standard x-ray film packs. This allows the operator to position the HDL at the proper distance and location for x-rays using various film pack sizes.

2. To avoid overheating, a 50% duty cycle with a 10 second on time has been chosen. The primary purpose of the controller module is to enforce this. The module also emits a warning tone when the operator activates the sight. A detailed description follows.

3. The controller module is a simple timing and power control system based on a microcontroller. The schematic is shown in figure 1. The module is powered from a 9 V battery, though future models will be powered from the 24 V available within the HDX. Switch S1 is a momentary contact SPST pushbutton which the operator closes to activate the LDM's. Upon sensing closure of the switch, the controller sounds a one second tone through the buzzer and closes relay R1 for 10 seconds. The switch-mounted LED, D1, is also illuminated, signifying the LDM's are on. After 10 seconds, the controller opens the relay, removing power from the LDM's. The controller also flashes D1 at 1 Hz during the 10 second cool-down period. This enforced delay helps prevent the LDM's from overheating and also saves the operator from remembering to turn the LDM's off. Switch S1 is ignored during this period, preventing the LDM's from being activated during the cool-down.

4. The controller chosen was the Signetics 87C752, a reduced I/O version of the Intel 8051 controller family. This was chosen because there was a readily available stock, and the built-in analog to digital converters (A/D's) and pulse-width modulator (PWM) circuitry could be useful in future iterations. Use of a microcontroller instead of discrete

circuitry also allowed a quick prototype design and flexibility in the timing functions.

5. Relay control of the power was also chosen for simplicity for fast prototyping. A relay could easily handle the current and future predicted power levels of the LDM's. The relay also did not require the design of driver circuitry and heat-sinking which would be required in a solid-state design.

6. U2 is a hex inverter which handles the driving of the high-current parts of the system (R1 and D1). This chip can handle much more current than the controller itself, and thus acts as a driver and buffer for the controller I/O ports.

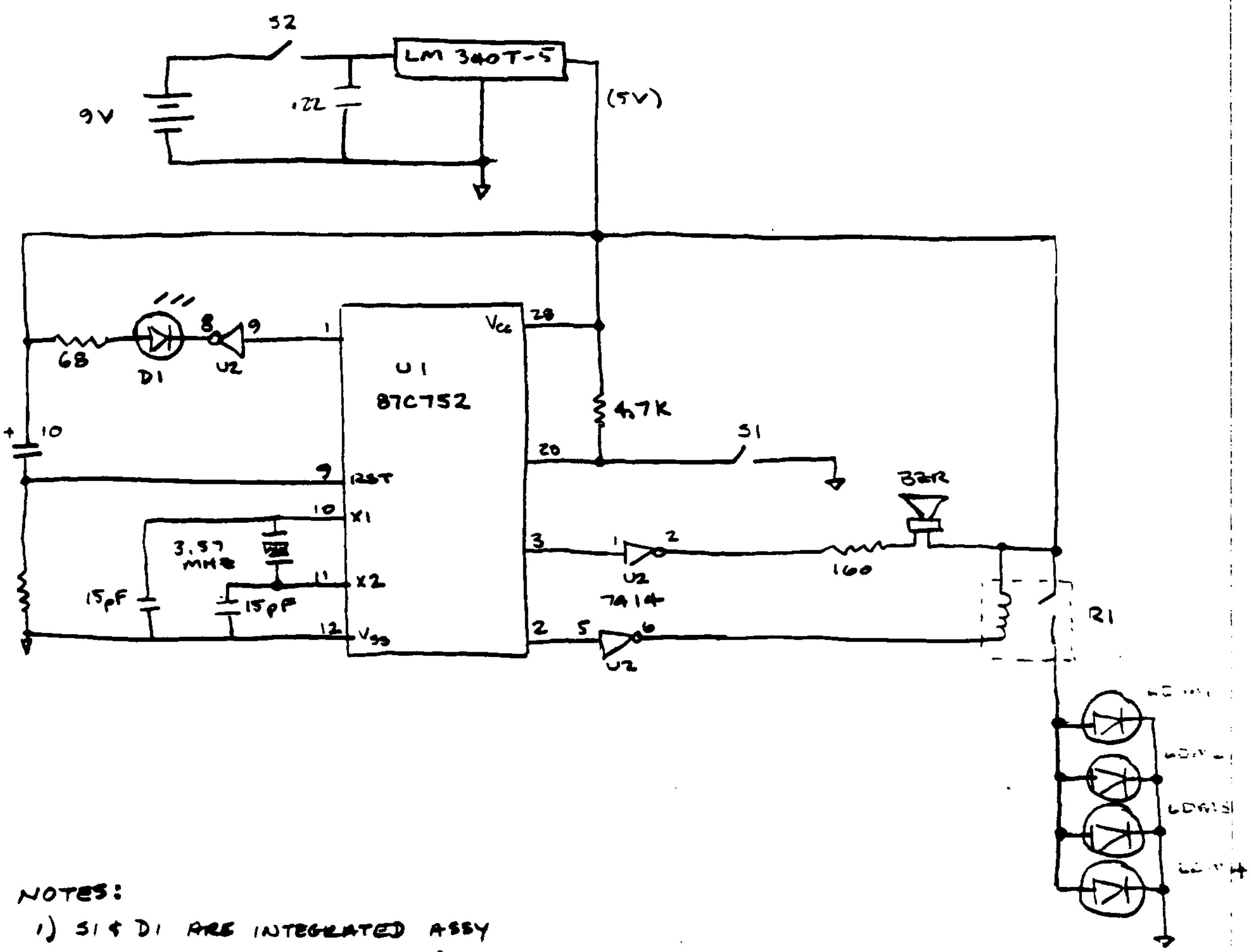
7. While a microcontroller may seem like overkill for a simple timing function, it offers expansion possibilities for future requirements. Using the A/D's, the controller could monitor battery charge, LDM temperature, and other sensor data. The PWM controller would allow rapid pulsing of the LDM's at higher power than their steady-state rating. This could increase light levels from the sight without adding lots of extra circuitry. It should be noted that the relay would have to be abandoned for an electronic switch (such as a power FET) to obtain the rapid switching times.

8. Future improvements should include replacing the relay with a FET, improving the visual indicator, D1, which may be too dim in bright light, and investigating a surface-mount design for decreased size and increased ruggedness.

Brian J. Mary

Brian J. Mary
Mechanical Engineer
Mechanical Systems Branch

cf:
Overman
Beard



NOTES:

1) S1 & D1 ARE INTEGRATED ASSY (NKK SWITCH JF15RP3DF)
2) LDM 1-4: IMATRONIC LDM-135
3) BUZZER: PANASONIC EFB-CC28C15
4) R1 : EAC 20-1051-10

HDX SIGHT CONTROLLER
FIRST PROTOTYPE

F-5

15 JAN 92
B. MAILY

FIG. 1

Appendix G
(of Interim Report)

Specifications of the Laser Diode Modules

iMATRONIC

APPLICATION NOTE
LDM135
Laser Diode Module

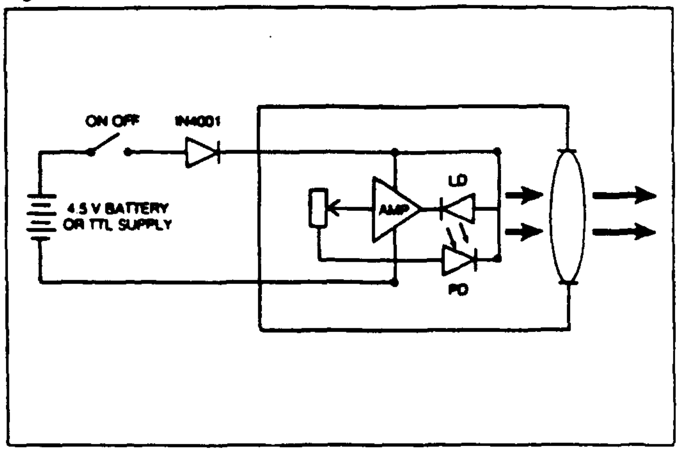
Introduction

The LDM135 is a self-contained solid-state laser diode module which emits light in the visible spectrum at a wavelength of 660-685nm. Its features include output power stabilisation, built in drive circuitry, collimating optics (user-adjustable) and TTL logic level compatability. It is an ideal replacement for a Helium Neon laser and supply in many applications, and in many circumstances will prove more suitable due to its superior ruggedness and small size.
It is shown in schematic form in Figure 1.

Typical Applications include:

- **Pilot beam for alignment**
- **Measurement**
- **Targeting**
- **Analysis**
- **Bar code readers**
- **Robotic control**
- **Positioning**
- **Security detection**

Figure 1: Laser Diode Module 135 Typical Application



Electrical Specification

Connections	Positive - red flying lead Negative - black flying lead
Supply	3.0-5.25v (0.5mW, 1mW version) 4.0-5.25v (2mW, 3mW version)
Isolation	Supply to metal body 40v peak
Reverse Protection	None fitted to allow low operating voltages. Device will survive five second polarity reversal at rated voltage. If greater reverse protection is required, a series diode (eg IN4001) may be used.
Handling	No special precautions as static sensitive laser diode is fully protected. Obey maximum voltage and temperature ratings at all times.
Stability	Optical power stabilised using integral photodiode to better than 5% over operating voltage range.
Adjustment	0.5mW device : set to meet Class II (<1mW) 1mW device : set to meet Class II (<1mW) 2mW device : set to meet Class IIIa (<5mW) 3mW device : set to meet Class IIIa (<5mW)
Supply rail rejection	20:1

Mechanical Specification

Size	Diameter : 16mm Length : 49mm Flying leads : 250mm
Material	Dural body, anodised to 10 microns
Stability	Pointing stability <2mrad

Complete with lens adjusting tool

Quality

All LDM135s have a MTBF of >10,000 hours when operated within maximum ratings.

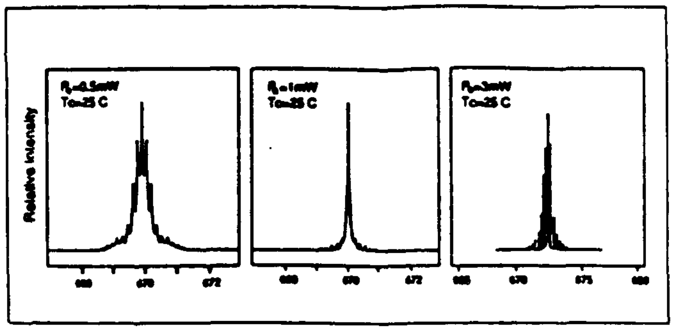
Temperature	: operating -10° C to +30° C
Storage/transit	: -10°C to +50°C

Warning: **To prevent excessive temperature rise, mount the unit on an aluminium heatsink of at least 24 sq cm area. Do not operate in unventilated enclosures. Excessive temperature will drastically shorten the life of the laser diode.**

Optical Characteristics

	0.5mW	1mW	2mW	3mW
Wavelength	660-685nm.	Typically 675nm at 25° C but drifts 0.25nm/°C		
Divergence	<0.5mr	<0.5mr	<0.5mr	<0.5mr
Beam size	5mm dia.	5mm dia.	6mm x 2mm	6mm x 2mm
Output (mW)	0.5± 10%	0.9± 10%	2.0± 10%	3.0± 10%
Coherence length	>5cm	> 10cm	>5cm	>5cm
Focussing range	down to 150mm	down to 150mm	down to 20mm	down to 20mm
Spot size	100 micron	100 micron	50 micron	50 micron
Polarisation	> 10:1	> 10:1	> 10:1	> 10:1
Spectral purity	See Fig 2	See Fig 2	See Fig 2	See Fig 2

Figure 2: Power Dependency of Longitudinal Mode (Linear)



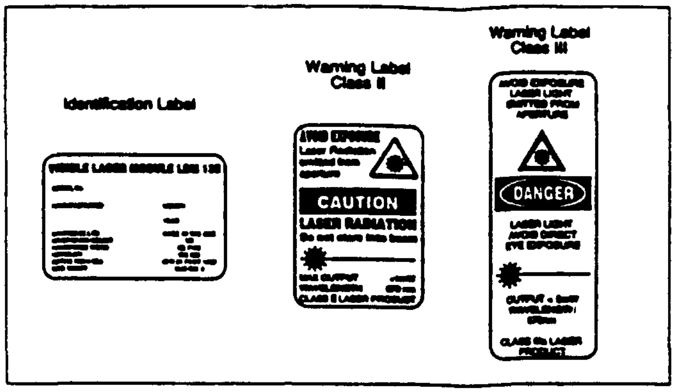
Safety

The LDM135 is supplied on an OEM basis for incorporation into other products.

The output is factory pre-set to meet Class II requirements (0.5mW and 1mW) or Class IIIa requirements (2mW and 3mW) of BS7192, IEC825 and FDA 21CFR PART 1000

To comply with these requirements it is necessary for the final product to either totally enclose the laser emission in accordance with Class I requirements or if the beam is accessible to carry the appropriate Class II or III warning lables, see Figure 3 for details.

Figure 3: Identification and Warning Labels



Important: Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure. No user serviceable parts inside.

This information is subject to change without notice, and is presented only as a guide for the applications of our products. No liability can be assumed for loss or damage, however caused, from the data in this note.

Many variations of the above specification are possible and Imatronic is able to design alternative packages to suit individual product needs.

IMATRONIC

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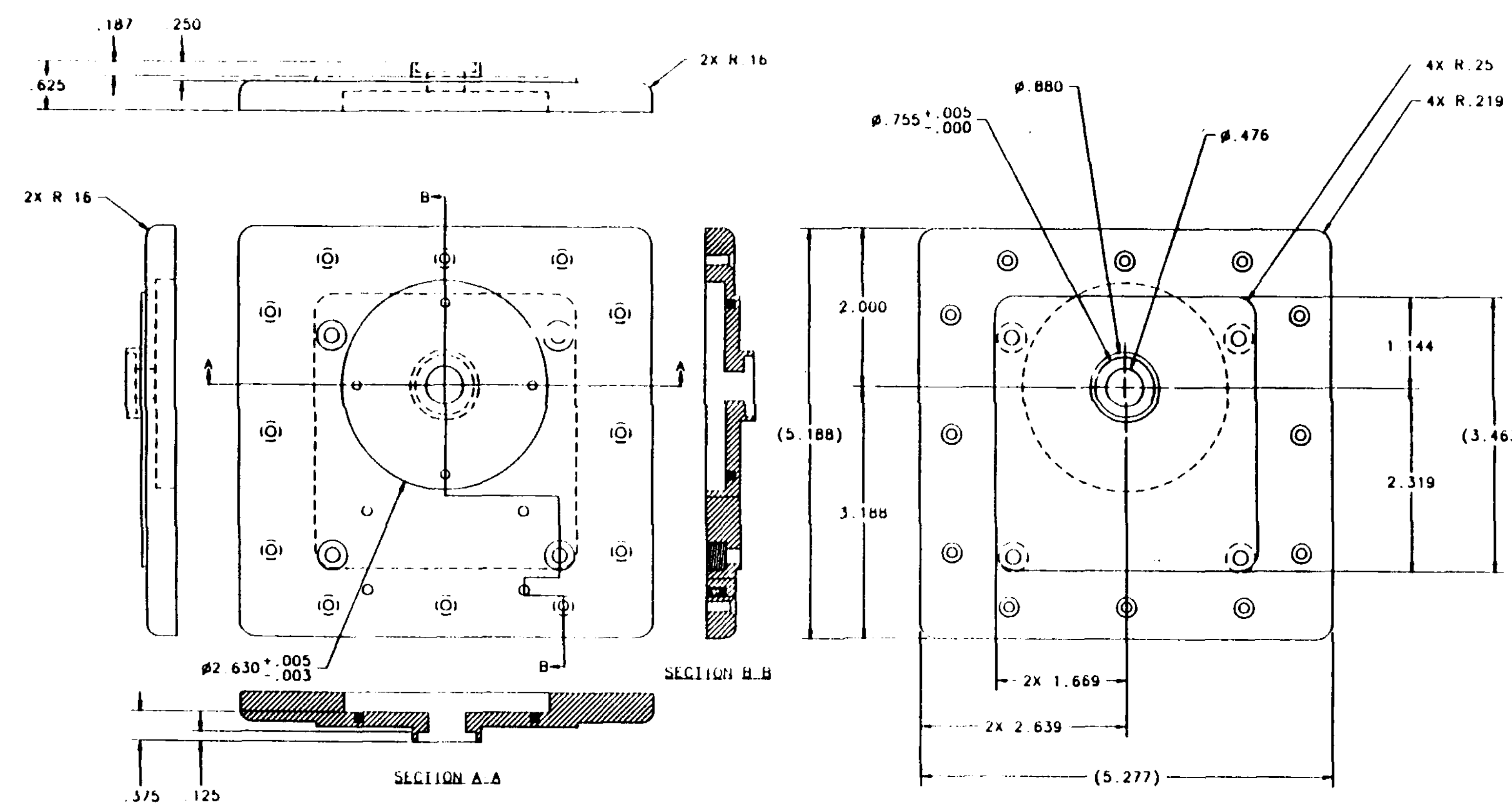
PO Box 520
Batavia, IL 60510
USA
Tel: (708) 406-1920
Fax: (708) 879-6749

Appendix B

Mechanical Drawings of XRS2

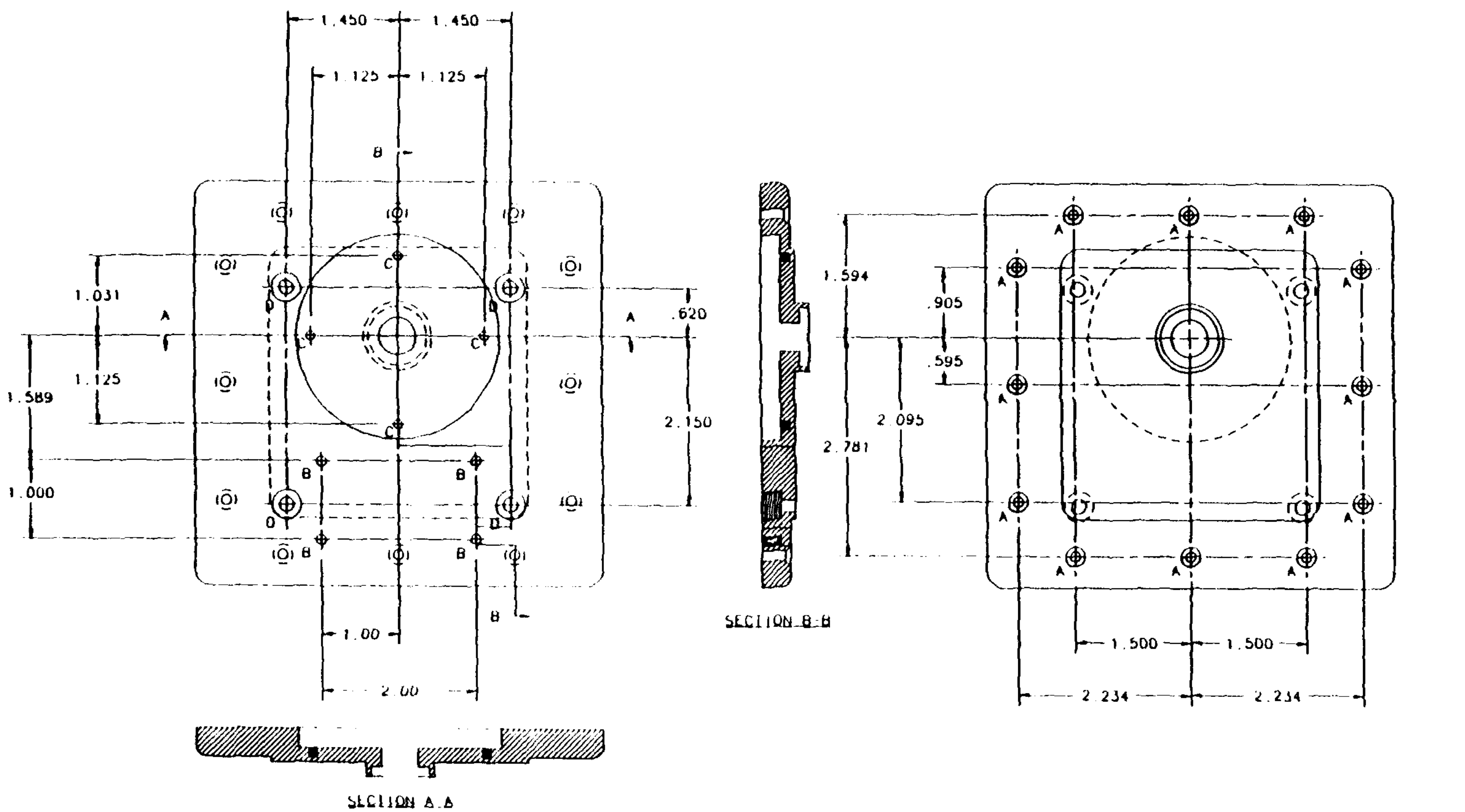
NOTES:
1. INTERPRET DRAWING IAW DOD STD 100
2. MATERIAL: ALUMINUM ALLOY.
3. REMOVE ALL BURRS AND SHARP EDGES.
4. FINISH: ANODIZE PER MIL A 8625, TYPE II, CLASS 2, DYED FLAT BLACK.

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	XO	INITIAL RELEASE	920713	
	XA	MODIFIED HOLE "A" DIA. AND LOCATION.	920724	
	XB	MODIFIED HOLE "D" DIAMETER AS REQUIRED.	920831	



		UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ON: DECIMALS (.X) ±.1 (.XX) ±.01 (.XXX) ±.005 ANGLES ±1°	92-07-13	UNITED STATES ARMY LABORATORY COMMAND HARRY DIAMOND LABORATORIES 2800 POWDER MILL RD. ADELPHI, MD 20783-1197
XRAY06				BASEPLATE, XRAY SIGHT
XRAY07				C 19202 XRAY01
XRAY08				SCALE 1:1 SHEET 1 OF 2
XRAY03	XRAY00			
NEXT ASSY	USED ON			
APPLICATION				

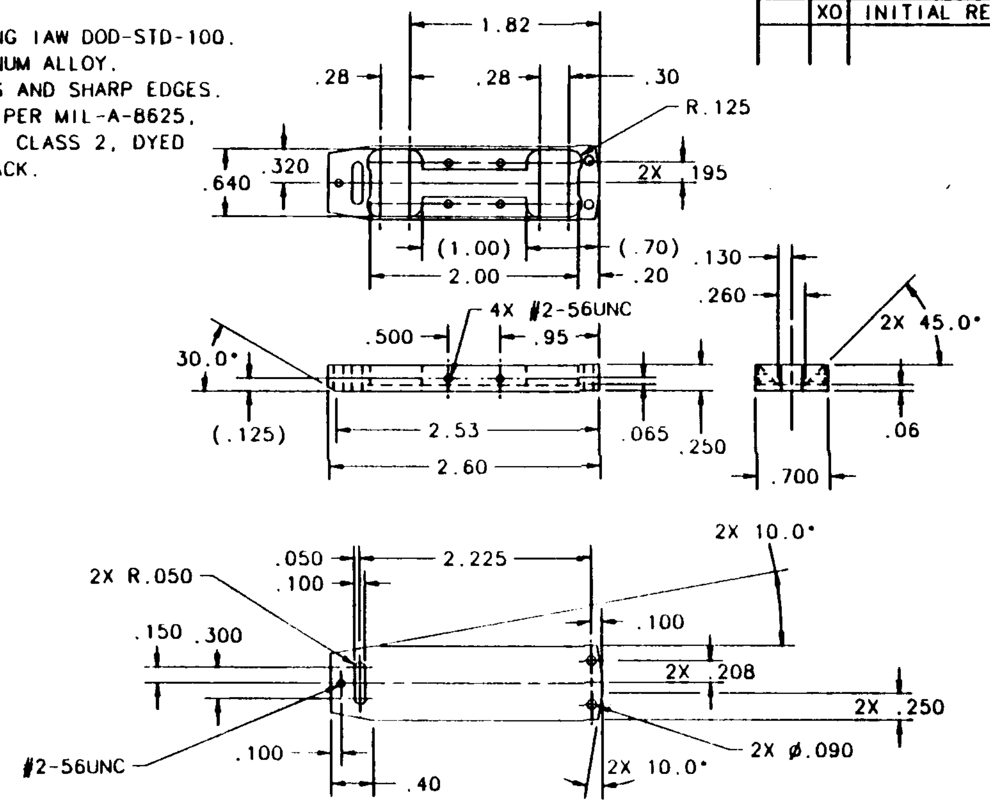
HOLE	DESCRIPTION	QTY
A	Ø .128 THUR HOLE	12
	Ø .250 CSK 82°	
B	#4 40UNC .250 DEEP	4
	HOLE SHALL NOT BREAK THROUGH	
C	#4 40UNC .125 DEEP	4
	HOLE SHALL NOT BREAK THROUGH	
D	Ø .185 THRU HOLE	4
	3/8-16UNC .250 DEEP	



C	19202	XRAY01
SCALE 1:1		SHEET 2 OF 2

NOTES:

1. INTERPRET DRAWING IAW DOD-STD-100.
2. MATERIAL: ALUMINUM ALLOY.
3. REMOVE ALL BURRS AND SHARP EDGES.
4. FINISH: ANODIZE PER MIL-A-8625, TYPE II, CLASS 2, DYED FLAT BLACK.



REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	XO	INITIAL RELEASE	920713	

XRAY05	XRAY03
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES.
TOLERANCES ON: DECIMALS
(.X) ±.1
(.XX) ±.01
(.XXX) ±.005
ANGLES ±1°

ORIG/ISSUE DATE 92-07-13
DRAFTSMAN
CHECKER
PROJ MGR
ENGR
CHGR
QA
APPROVED
DATE

UNITED STATES ARMY LABORATORY COMMAND
HARRY DIAMOND LABORATORIES
2800 POWDER MILL RD, ADELPHI, MD 20783-1197

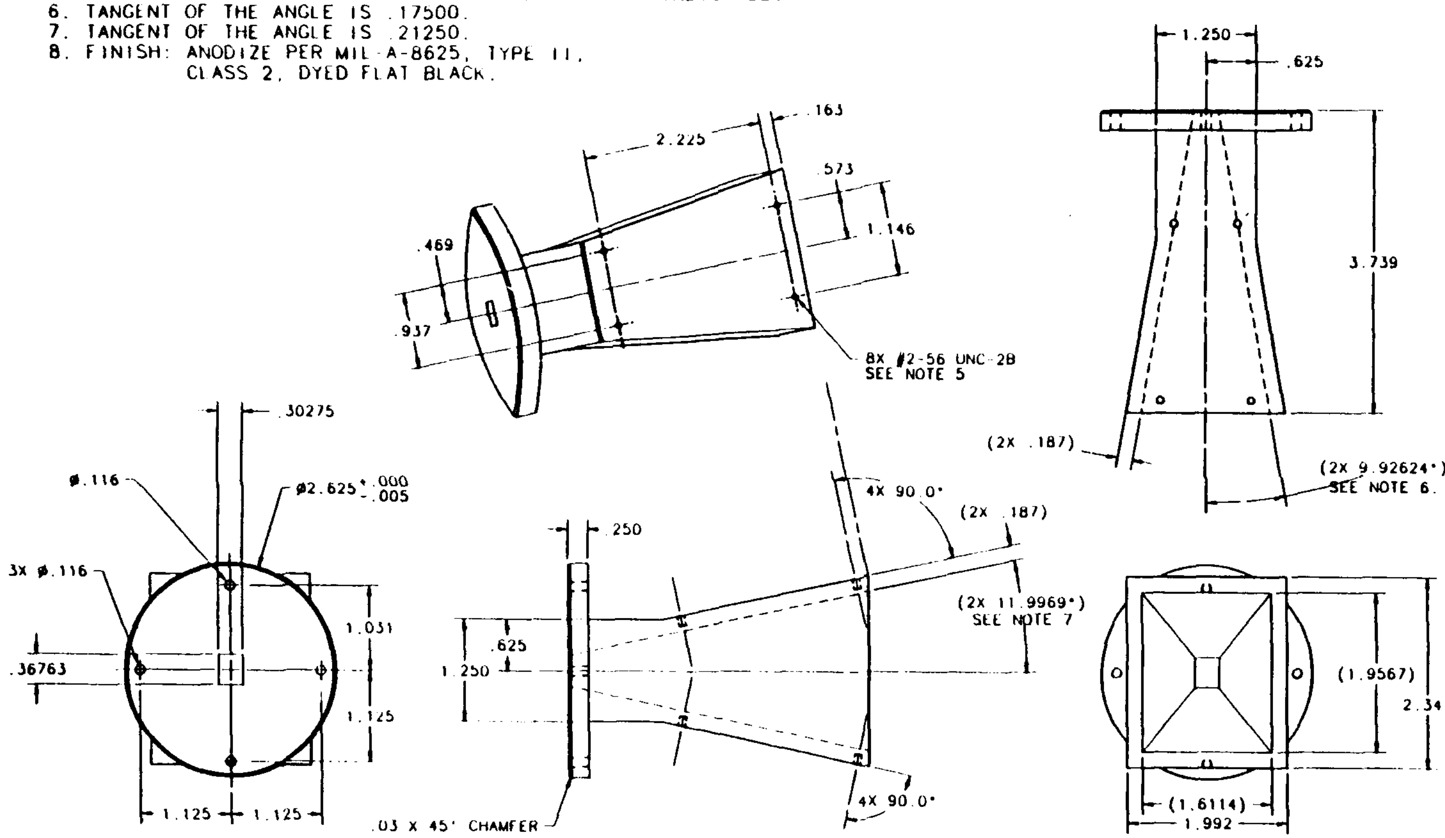
CARRIER, LDM, XRAY SIGHT

SIZE B | CAGE CODE 19202 | DWG NO. XRAY04
SCALE 1:1 | SHEET 1 OF 1

NOTES:

1. INTERPRET DRAWING IAW DOD STD-100.
2. MATERIAL: ALUMINUM ALLOY.
3. REMOVE ALL BURRS AND SHARP EDGES.
4. THE INTERIOR OF THE HORN SHALL BE CUT USING THE EDM MACHINE. THE EXCESS MATERIAL SHALL BE SAVED.
5. THREAD SHALL BE FULL. HOLE SHALL NOT BREAK THROUGH. HOLE SHALL BE PERPENDICULAR TO THE SURFACE AS INDICATED.
6. TANGENT OF THE ANGLE IS .17500.
7. TANGENT OF THE ANGLE IS .21250.
8. FINISH: ANODIZE PER MIL-A-8625, TYPE II, CLASS 2, DYED FLAT BLACK.

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	XO	INITIAL RELEASE	920713	
	XA	NOTES 6 AND 7 ADDED.	920831	



XRAY04	XRAY01	UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ON: DECIMALS (.X) ±.1 (.XX) ±.01 (.XXX) ±.005 ANGLES ±.5°
NEXT ASSY	USED ON	
APPLICATION		

92-07-13

UNITED STATES ARMY LABORATORY COMMAND
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HORN, XRAY SIGHT

SIZE C | CAGE CODE 19202 | DWG NO XRAY03

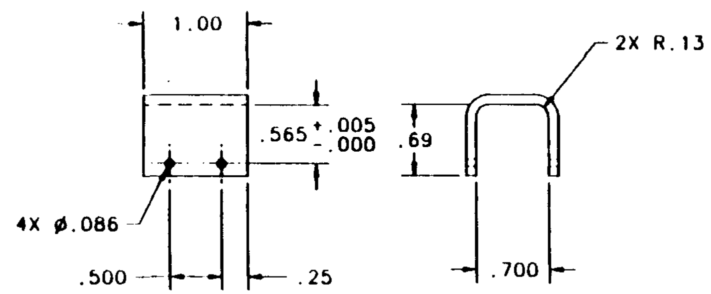
SCALE 1:1 | SHEET 1 OF 1

ZONE	REV	DESCRIPTION	DATE	APPROVED
	XO	INITIAL RELEASE	920713	

REVISIONS

NOTES:

1. INTERPRET DRAWING IAW DOD-STD-100.
2. MATERIAL: ALUMINUM ALLOY, SHEET STOCK, .094 THICK.
3. REMOVE ALL BURRS AND SHARP EDGES.
4. FINISH: ANODIZE PER MIL-A-8625, TYPE II, CLASS 2, DYED FLAT BLACK.



XRAY00	XRAY04
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES.
TOLERANCES ON: DECIMALS
(.X) ±.1
(.XX) ±.01
(.XXX) ±.005
ANGLES ±1°

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PROJ MGR
ENGR | ENGR
QA
APPROVED | DATE

UNITED STATES ARMY LABORATORY COMMAND
HARRY DIAMOND LABORATORIES
2800 POWDER MILL RD. ADELPHI, MD 20783-1197

BRACKET, LDM CARRIER

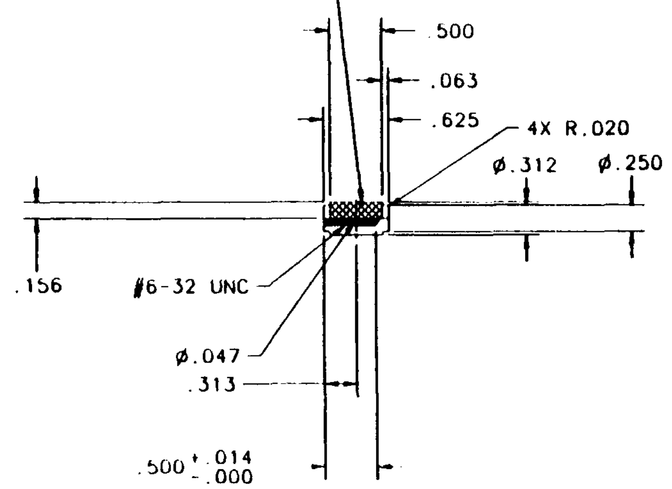
SIZE	CAGE CODE	DWG NO.
B	19202	XRAY05
SCALE 1:1		SHEET 1 OF 1

REVISIONS

ZONE	REV	DESCRIPTION	DATE	APPROVED
	XO	INITIAL RELEASE	920713	

NOTES:

1. INTERPRET DRAWING IAW DOD-STD-100.
2. MATERIAL: ALUMINUM ALLOY.
3. REMOVE ALL BURRS AND SHARP EDGES.
4. FINISH: ANODIZE PER MIL-A-8625, TYPE II, CLASS 2, DYED FLAT BLACK.



XRAY07	XRAY01
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES.
TOLERANCES ON: DECIMALS
(.X) ±.1
(.XX) ±.01
(.XXX) ±.007
ANGLES ±1°

ORIG/ISSUE DATE: 92-07-13
DRAFTSMAN | CHECKED
PROJ MGR
ENGR | ENGR
QA
APPROVED | DATE

UNITED STATES ARMY
LABORATORY COMMAND
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2800 POWDER MILL RD. ADELPHI, MD 20783-1197

THRU
BOLT

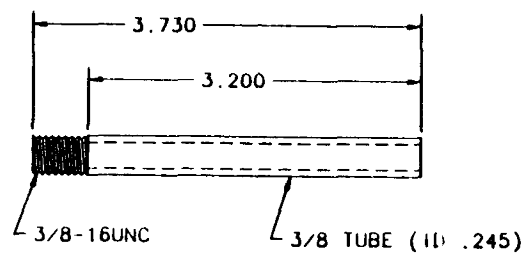
SIZE: B | CAGE CODE: 19202 | DWG NO: XRAY06
SCALE 1:1 | SHEET 1 OF 1

NOTES:

1. INTERPRET DRAWING IAW DOD-STD-100.
2. MATERIAL: ALUMINUM TUBING.
3. REMOVE ALL BURRS AND SHARP EDGES.
4. FINISH: ANODIZE PER MIL-A-8625, TYPE II, CLASS 2, DYED FLAT BLACK.

REVISIONS

ZONE	REV	DESCRIPTION	DATE	APPROVED
	XO	INITIAL RELEASE	920713	
	XA	MODIFIED AS BUILT	920831	



XRAY06	XRAY01
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES.
TOLERANCES ON:
DECIMALS
(.X) ±.1
(.XX) ±.01
(.XXX) ±.005
ANGLES ±1°

ORIG/ISSUE DATE: 92-07-13
DRAFTSMAN | CHECKER
PROJ MGR
ENGR | ENGR
QA
APPROVED | DATE

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GUIDE, THRU BOLT

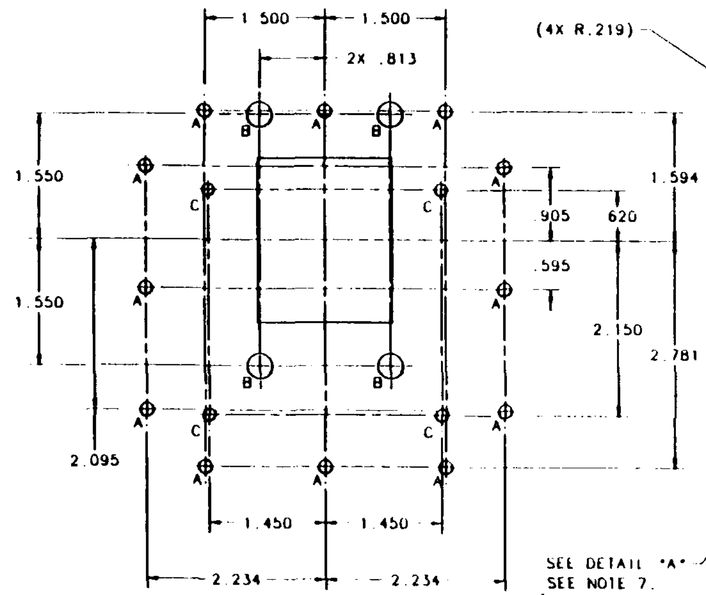
SIZE: B | CAGE CODE: 19202 | DWG NO. XRAY07
SCALE 1:1 | SHEET 1 OF 1

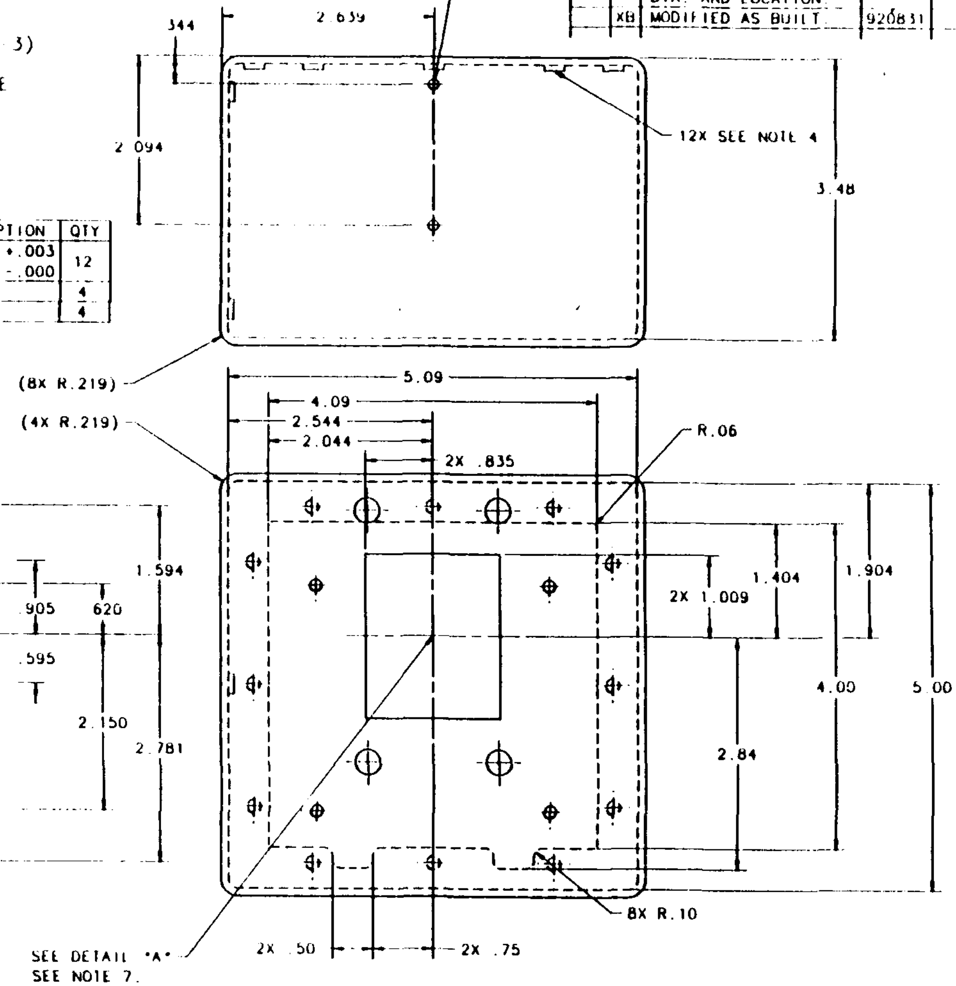
REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	XO	INITIAL RELEASE	920713	
	XA	MODIFIED HOLE "A" DIA. AND LOCATION	920724	
	XB	MODIFIED AS BUILT	920831	

NOTES:
1. INTERPRET DRAWING IAW DOD-STD-100.
2. MATERIAL: ALUMINUM ALLOY, 6061-T6, SHEET STOCK, .094 THICK.
3. REMOVE ALL BURRS AND SHARP EDGES.
4. INSTALL SELF-CLINCHING NUTS (PEM PART #CLS 440 3) AFTER FINAL FINISH.
5. ALL SEAMS SHALL HAVE CONTINUOUS WELDS OF A SIZE EQUAL TO THE THICKNESS OF THE MATERIAL JOINED. ALL EXTERIOR WELDS SHALL BE GROUND SMOOTH.
6. ALL INSIDE BEND RADII .12 MINIMUM.
7. HOLES "A" ARE LOCATED ON THE BACK SURFACE
8. FINISH: ANODIZE PER MIL-A-8625, TYPE II, CLASS 2, DYED FLAT BLACK.

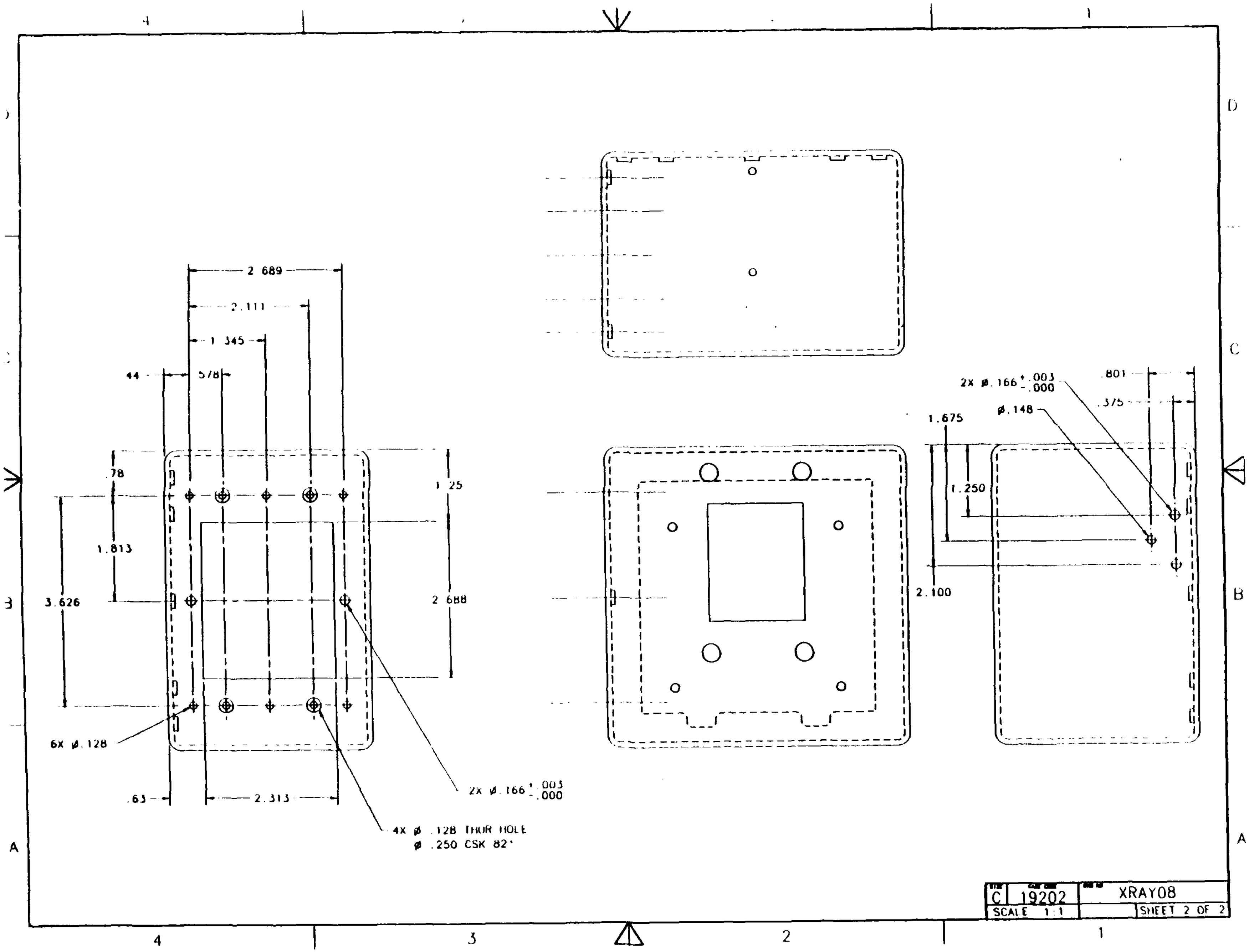
HOLE	DESCRIPTION	QTY
A	ø .166 +.003 -.000	12
B	ø .313	4
C	ø .166	4

DETAIL "A"





XRAY00	XRAY01	UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ON: DECIMALS (.X) ±.1 (.XX) ±.01 (.XXX) ±.005 ANGLES ±1°	92-07-13	UNITED STATES ARMY LABORATORY COMMAND HARRY DIAMOND LABORATORIES 2800 POWDER MILL RD. ADELPHI, MD 20783-1197
NEXT ASSY	USED ON			COVER, XRAY SIGHT
APPLICATION				SIZE C CAGE CODE 19202 DWG NO XRAY08
				SCALE 1:1 SHEET 1 OF 2

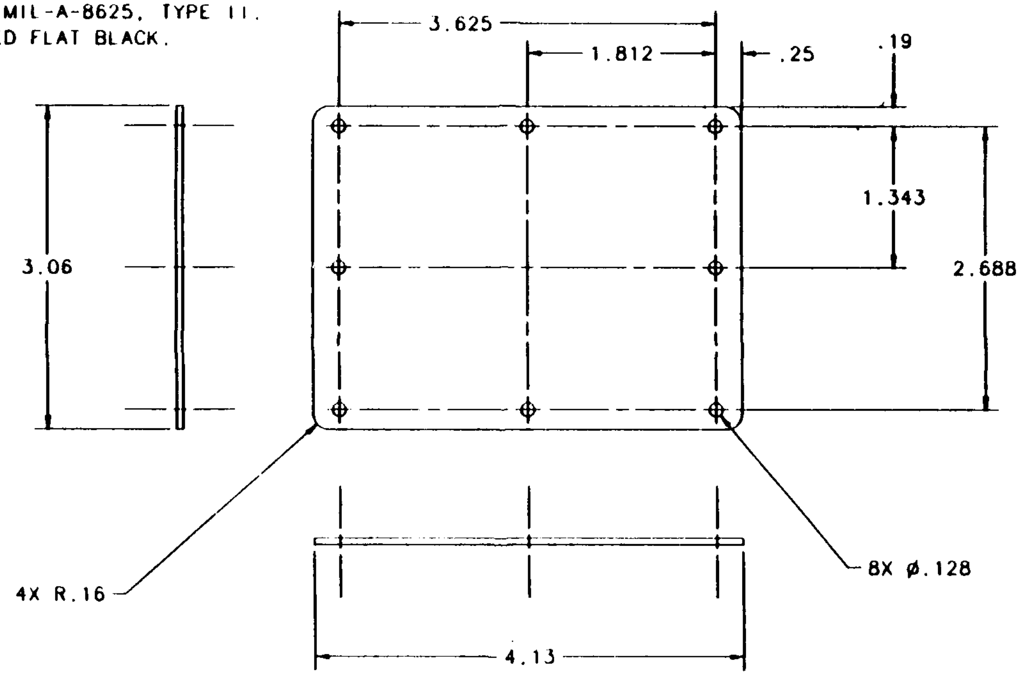

2 689
2.111
1 345
44
578
.78
1.813
3.626
1 25
2 688
6X ø.128
.63
2.313
2X ø.166 +.003 -.000
4X ø .128 THUR HOLE
ø .250 CSK 82°
2X ø.166 +.003 -.000
ø.148
.801
.375
1.675
1.250
2.100
C
19202
XRAY08
SCALE 1:1
SHEET 2 OF 2

NOTES;

1. INTERPRET DRAWING IAW DOD-STD-100.
2. MATERIAL: ALUMINUM ALLOY, SHEET STOCK, .063.
3. REMOVE ALL BURRS AND SHARP EDGES.
4. FINISH. ANODIZE PER MIL-A-8625, TYPE II, CLASS 2, DYED FLAT BLACK.

REVISIONS

ZONE	REV	DESCRIPTION	DATE	APPROVED
	XO	INITIAL RELEASE	920713	



XRAY00	XRAY08
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES.
TOLERANCES ON: DECIMALS
(.X) ±.1
(.XX) ±.01
(.XXX) ±.005
ANGLES ±1°

ORIG/ISSUE DATE 92-07-13
DRAFTSMAN CHECKER
PROJ MGR
ENGR ENGR
QA
APPROVED DATE

UNITED STATES ARMY LABORATORY COMMAND
HARRY DIAMOND LABORATORIES
2800 POWDER MILL RD. ADELPHI, MD 20783-1197

COVER, BATTERY, XRAY SIGHT

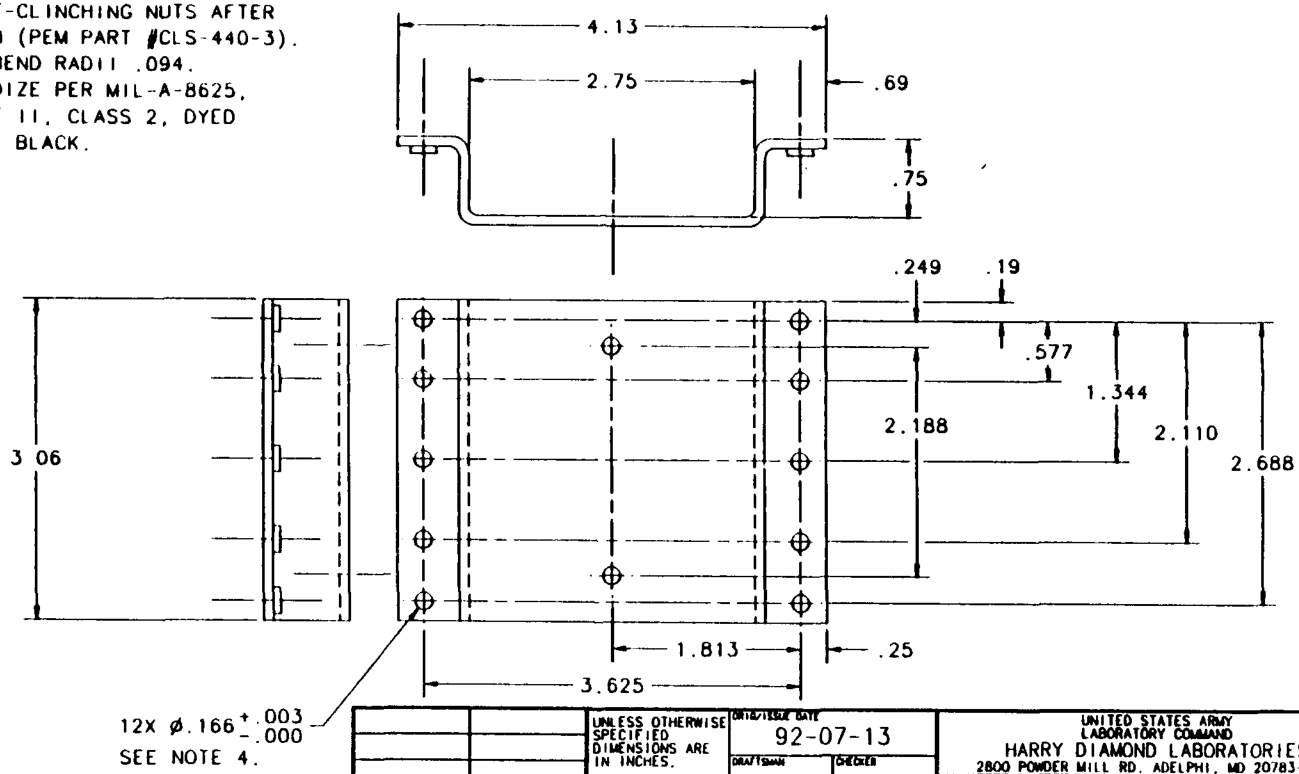
SIZE B | CAGE CODE 19202 | DWG NO. XRAY10
SCALE 1:1 | SHEET 1 OF 1

NOTES:

1. INTERPRET DRAWING IAW DOD-STD-100.
2. MATERIAL: ALUMINUM ALLOY SHEET STOCK, .094 THICK.
3. REMOVE ALL BURRS AND SHARP EDGES.
4. INSTALL SELF-CLINCHING NUTS AFTER FINAL FINISH (PEM PART #CLS-440-3).
5. ALL INSIDE BEND RADII .094.
6. FINISH: ANODIZE PER MIL-A-8625, TYPE II, CLASS 2, DYED FLAT BLACK.

REVISIONS

ZONE	REV	DESCRIPTION	DATE	APPROVED
	XO	INITIAL RELEASE	920713	
	XA	MODIFIED AS BUILT	920831	



XRAY00	XRAY08
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES.
TOLERANCES ON: DECIMALS
(.X) ±.1
(.XX) ±.01
(.XXX) ±.005
ANGLES ±1°

ORIG/ISSUE DATE 92-07-13
DRAFTSMAN | CHECKER | PROJ MGR | ENGR | ENGR | QA | APPROVED | DATE

UNITED STATES ARMY
LABORATORY COMMAND
HARRY DIAMOND LABORATORIES
2800 POWDER MILL RD. ADELPHI, MD 20783-1197

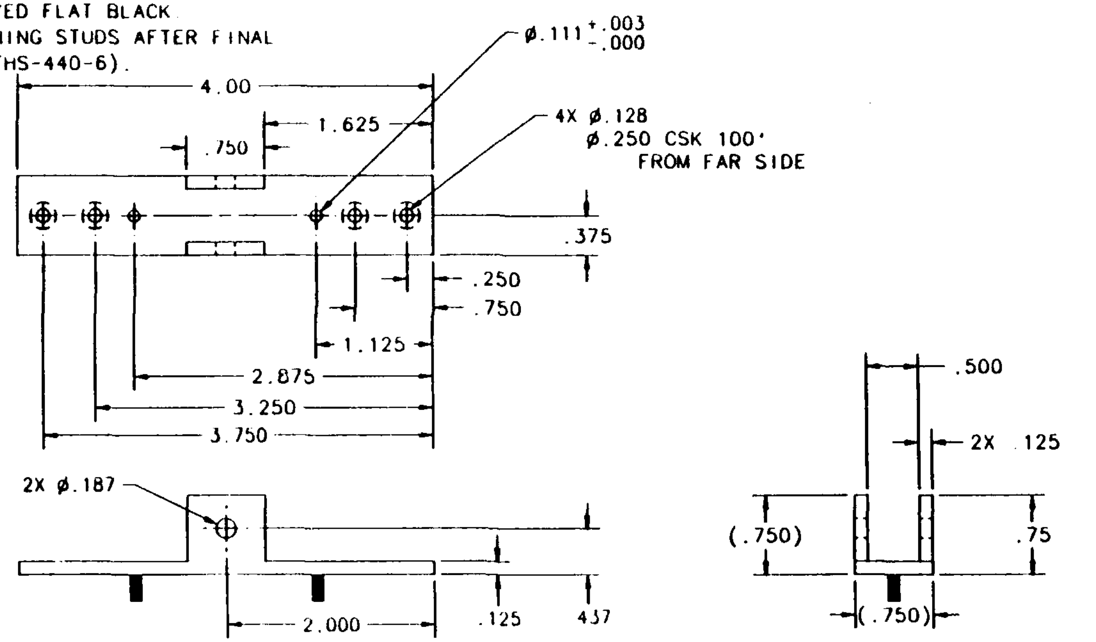
BRACKET, BATTERY, XRAY SIGHT

SIZE B | CAGE CODE 19202 | DWG NO. XRAY11
SCALE 1:1 | SHEET 1 OF 1

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	XO	INITIAL RELEASE	920806	
	XA	MODIFIED AS BUILT	920831	

NOTES:

1. INTERPRET DRAWING IAW DOD-STD-100.
2. MATERIAL: ALUMINUM SQUARE TUBE .750 x .750.
3. REMOVE ALL BURRS AND SHARP EDGES.
4. FINISH: ANODIZE PER MIL-A-8625, TYPE II, CLASS 2, DYED FLAT BLACK.
5. INSTALL SELF-CLINCHING STUDS AFTER FINAL FINISH (PEM PART #FHS-440-6).



XRAY14	XRAY08
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES.
TOLERANCES ON: DECIMALS
(.X) ±.1
(.XX) ±.01
(.XXX) ±.007
ANGLES ±1°

92-08-06

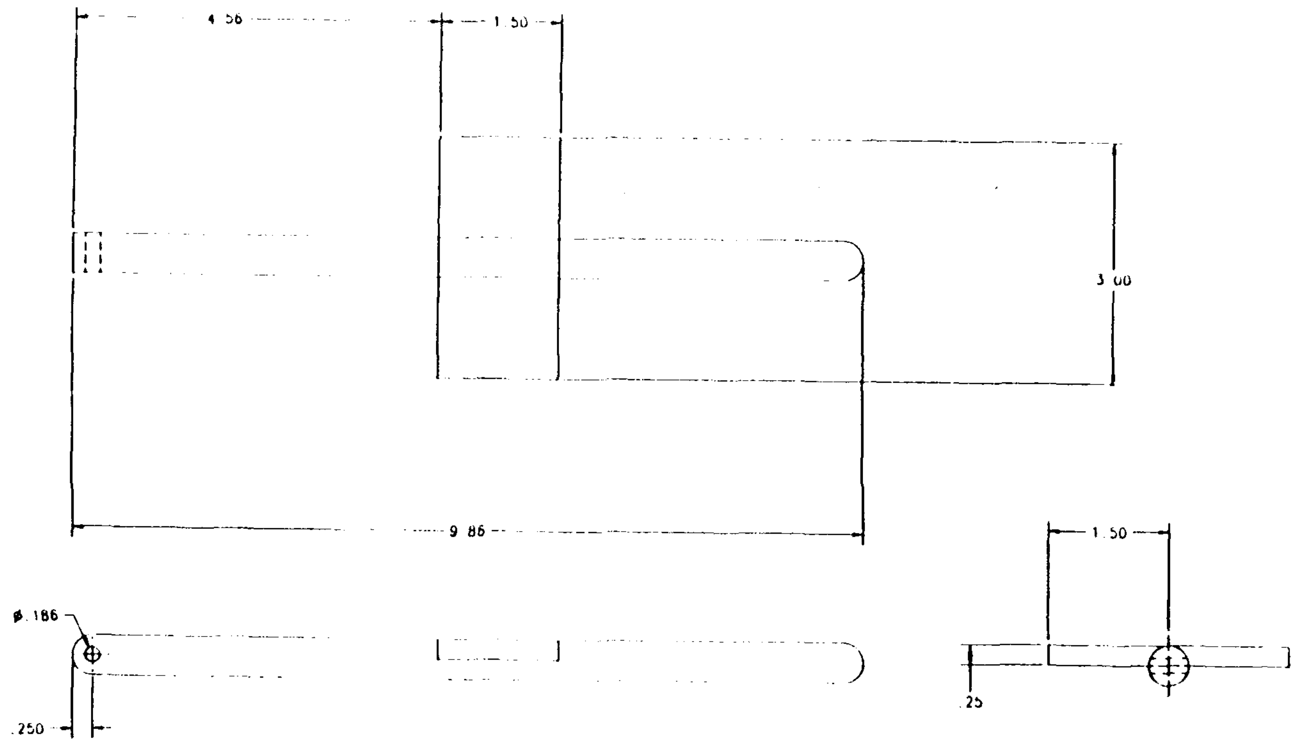
UNITED STATES ARMY
LABORATORY COMMAND
HARRY DIAMOND LABORATORIES
2800 POWDER MILL RD. ADELPHI, MD 20783-1197

HING, SAFETY ROD, XRAY SIGHT

SIZE B | CAGE CODE 19202 | DWG NO. XRAY13
SCALE 1:1 | SHEET 1 OF 1

NOTES:
1. INTERPRET DRAWING IAW DOD STD 100
2. MATERIAL: POLYCARBONATE.
3. REMOVE ALL BURRS AND SHARP EDGES.

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	XO	INITIAL RELEASE	920806	



XRAY00	XRAY13
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES.
TOLERANCES ON DECIMALS
(.X) ±.1
(.XX) ±.01
(.XXX) ±.005
ANGLES ±1°

92-08-06

UNITED STATES ARMY LABORATORY COMMAND
HARRY DIAMOND LABORATORIES
2800 POWDER MILL RD. ADELPHI, MD 20783-1197

ROD,
SAFETY,
XRAY SIGHT

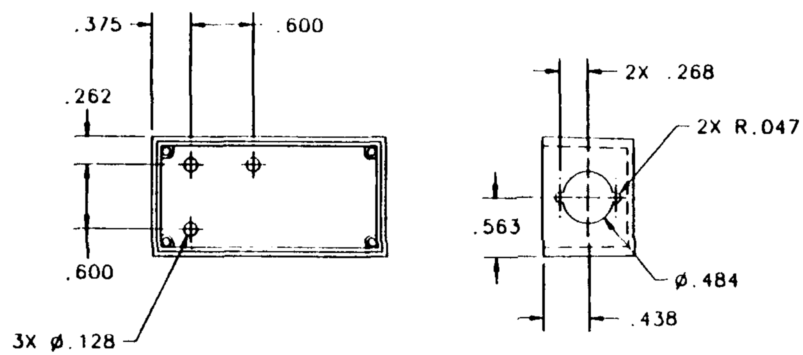
C 19202 XRAY14

SCALE 1:1 SHEET 1 OF 1

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	XO	INITIAL RELEASE	920813	
	XA	MODIFIED AS BUILT	920831	

NOTES:

1. INTERPRET DRAWING IAW DOD-STD-100.
2. MATERIAL: POMONA BOX.
3. REMOVE ALL BURRS AND SHARP EDGES.
4. FINISH: ANODIZE PER MIL-A-8625, TYPE II, CLASS 2, DYED FLAT BLACK.



XRAY00	XRAY08
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES.
TOLERANCES ON: DECIMALS
(.X) ±.1
(.XX) ±.01
(.XXX) ±.007
ANGLES ±1°

ORIG/ISSUE DATE 92-08-13
DRAFTSMAN | CHECKER
PROJ MGR
ENGR | ENGR
QA
APPROVED | DATE

UNITED STATES ARMY LABORATORY COMMAND
HARRY DIAMOND LABORATORIES
2800 POWDER MILL RD. ADELPHI, MD 20783-1197

BOX, SWITCH, XRAY SIGHT

SIZE B | CAGE CODE 19202 | DWG NO. XRAY15
SCALE 1:1 | SHEET 1 OF 1

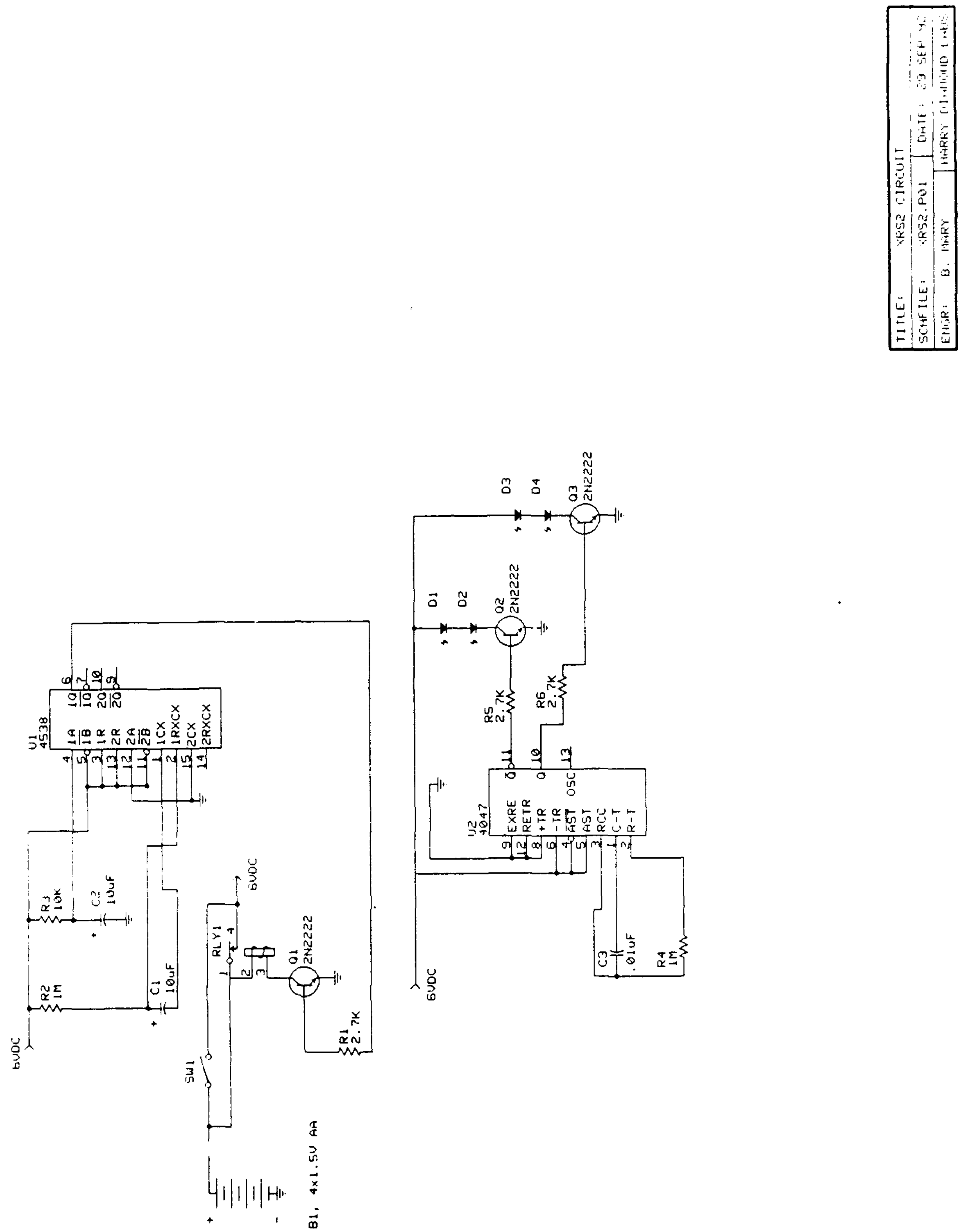


Figure B-1

Distribution:

SLCHD-D, J. Reed

SLCHD-TA, P. Ingersoll

SLCHD-TA-ES, R. Goodman

SLCHD-TA-MS
D. Overman
J. Beard
E. Marquis
B. Mary
C. Robinson

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Appendix C

Description of Electronics for XRS2

A schematic of the electronics used in XRS2 is shown in fig. B-1. The electronics consists of two integrated circuits (IC) which operate as timers controlled by simple resistor/capacitor (RC) time constants. One IC (U1) is configured as a ten second timer. After a short delay following application of power (to allow the circuit voltages to stabilize), this IC closes the relay for approximately 10 seconds, keeping power on the system after the switch is released.

The second IC, U2, is configured as a 20Hz oscillator. When power is applied to this circuit, the lasers are flashed in pairs at a rate of approximately 20Hz. Through the use of complementary outputs from U2, only one pair is illuminated at a time. This is necessary to stay within the current output limits of the batteries. The lasers are paired as opposite corners, so that if one driver circuit should fail, the two lasers left would define a pair of diagonally opposed corners of the x-ray beam. A technical description of the circuit is presented next.

SW1 is the control button, a momentary, normally open, push-button switch. When closed, it applies power to the system. After a short delay determined by R3 and C2, U1 latches the relay closed for approximately 10 seconds. This time is determined by R2 and C1, where T=RC [T in seconds, R in ohms, C in farads].

U1 is configured as a one-shot with a ten second output pulse. The delay (R3, C2) allows the circuit to stabilize before triggering the one-shot. The on time of the lasers (D1-D4) can be varied by changing R2 and C1.

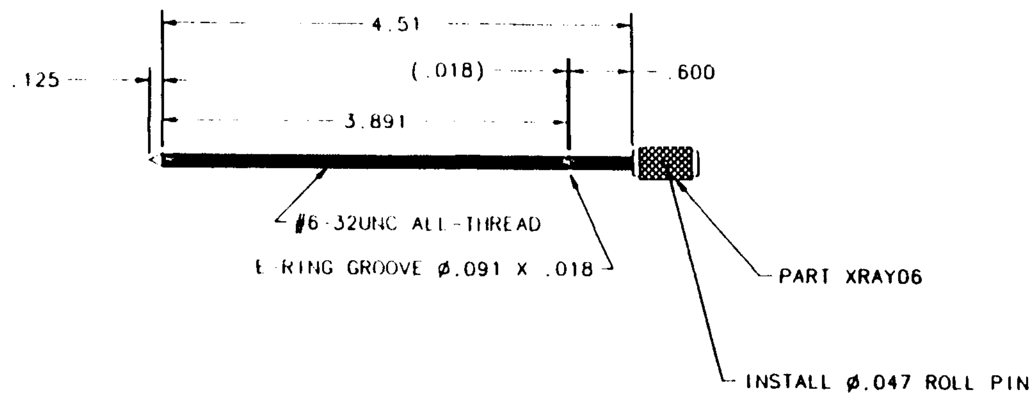
U2 is configured as a free-running astable multivibrator running at approximately 20Hz on the Q outputs (the multivibrator is running at about 40Hz internally). The frequency is determined by R4 and C3. Complementary outputs Q and /Q drive a pair of transistors, Q2 and Q3, in the open collector mode. These transistors sink current from two pairs of laser diodes.

The 4000-series CMOS logic was chosen over the 7400-series for its wide operating voltage range. 7400-series logic requires 5VDC, ±10%, where 4000-series will run using 3-16VDC. This eliminates the need for a voltage regulator to put out a exact 5VDC. The lasers will operate with supply voltages ranging from 4.5-6VDC. This assures maximum use of the batteries over their life span.

NOTES

1. INTERPRET DRAWING IAW DOD STD-100.
2. REMOVE ALL BURRS AND SHARP EDGES.

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	XO	INITIAL RELEASE	920713	



NEXT ASSY	USED ON
XRAY07	XRAY01
APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES.
TOLERANCES ON DECIMALS
(.X) ±.1
(.XX) ±.01
(.XXX) ±.005
ANGLES ±1°

ORIG/ISSUE DATE 92-07-13
DRAFTSMAN / CHECKER / PROJ MGR / ENGR / ENGR / QA / APPROVED / DATE

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THRU
BOLT
ASSEMBLY

SIZE	CAGE CODE	DWG NO
B	19202	XRAY16
SCALE 1:1		SHEET 1 OF 1